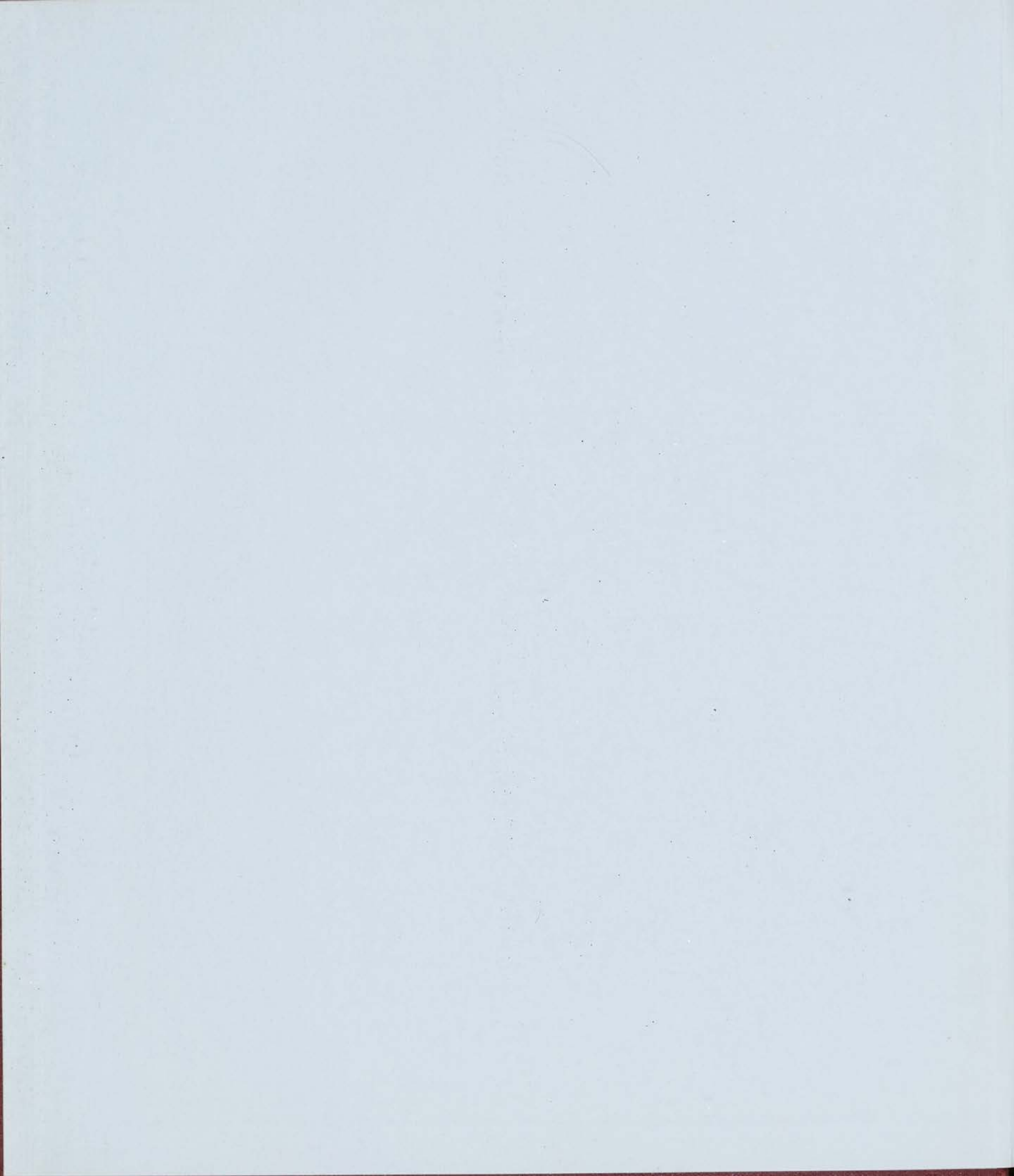


RULES AND REGULATIONS FOR THE  
CONSTRUCTION AND CLASSIFICATION  
OF STEEL SHIPS  
1976























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## Register Books

issued by the Committee of Lloyd's Register of Shipping

### **Lloyd's Register Book**

This publication is comprised of the Register of Ships, the List of Shipowners, and the Appendix, which are issued annually in July, August, and January respectively.

**The Register of Ships** (in two volumes A-L and M-Z) contains the names, classes and general information concerning the ships classed by Lloyd's Register of Shipping (including the British Corporation Register); also particulars of all known ocean-going merchant ships in the world, of 100 tons gross and upwards.

The second volume (M-Z) also contains ship-borne barges, docking installations, liquefied gas carriers, refrigerated cargo installations, refrigerated cargo containers, refrigerated stores and container terminals classed with Lloyd's Register, and off-shore units.

The Register is kept up to date by means of cumulative monthly Supplements containing changes of name, ownership, flag, tonnage, etc, for all ships, together with a cumulative list of new ships not recorded in the Register itself. A separate monthly and cumulative Classification Survey Dates Supplement containing the latest survey records for all Lloyd's Register classed ships is available if required.

**A Weekly List of Alterations** in the Register of Ships is also published.

**The List of Shipowners** contains a list of owners and managers of the ships recorded in the Register with their fleets as well as lists of former names of ships and compound names of ships.

**The Appendix** contains lists of shipbuilders with existing ships they have built; marine enginebuilders and boilermakers; dry and wet docks; telegraphic addresses and codes used by shipping firms; marine insurance companies and marine associations.

**Statistical Tables** are issued gratis to subscribers to the Register Book.

### **Lloyd's Register of Yachts**

Published annually in April, this volume contains detailed information relating to yachts classed by the Society: names, dimensions, etc, of other British and overseas yachts whose particulars are known; list of one-design and restricted classes; national authorities and list of sail numbers of certain classes of racing yachts; geographical list of yacht clubs; list and particulars of yacht and sailing clubs with the names of officers; index of signal letters; late names of yachts; names and addresses of yacht builders and designers; list of owners with their addresses, clubs and the names of their yachts.

### **List of National Authorities and Sail Numbers of Racing Yachts**

This section of the Register of Yachts may be purchased separately.

### **Lloyd's Register of American Yachts**

This Register is available annually in April from the Society's Office at 17 Battery Place, New York, NY 10004, USA.

The book contains the names, dimensions, and full particulars of the yachts of the United States and Canada, so far as they are ascertainable; reproductions in colour of the burgees of yacht clubs and the private signals of yachtsmen; geographical list of yacht clubs; list and particulars of yacht clubs with the names of their officers; index of signal letters; late names of yachts; list of yacht owners of the United States and Canada, with their addresses, clubs and the names of their yachts.

### **Club Burgees and Private Signals** (in colour).

This section of the Register of American Yachts may be purchased separately.



**Rule Books and other publications**  
issued by the Committee of Lloyd's Register of Shipping

**Rules and Regulations for the Construction and Classification of Steel Ships**

These Rules contain:

Chapter	Regulations
A	General information
B	Classification regulations
C	Periodical survey regulations
	Construction Rules
D	Hull construction
E	Pumping and piping
F	Fire protection, detection and extinction
G	Conditions for survey of machinery during construction
H	Main and auxiliary engines and associated machinery components
J	Boilers and other pressure vessels
K	Spare gear for steam and oil engine machinery installations
L	Control engineering equipment
M	Electrical equipment and electric propelling machinery
N	Refrigerated cargo installations
P	Materials for ship construction
Q	Materials for boiler, pressure vessel and machinery construction
	Appendices:
	1. Conversion tables for use with Chapters P and Q
	2. Approved manufacturers and proving establishments
R	Provisional Rules and Guidance Notes
(B)	Plastic pipes
(C)	Classification of nuclear ships
(D)	Metal pipes for water services
(E)	Torsional vibration characteristics of main and auxiliary oil engines
(G)	Propeller – hull clearances
(H)	Repairs by welding:
	1. New steel castings for crankshafts
	2. New copper alloy propeller and blade castings
(J)	Classification of tankers for the carriage of liquid chemicals in bulk
(K)	Periodical in-water survey of large ships

**Extracts from the Rules for Steel Ships**

The following Extracts contain Chapters selected from the Rules:

Extract	Chapter(s)
No. 1	B, C, N8 and R (J and K)
No. 2	B, C, D, P (including Appendices) and R (J and K)
No. 3	B, C, E, F, G, H, J, K, L, Q (including Appendices) and R (B, D, E, G, H, J and K)
No. 4	E, G, H, K, L, Q (including Appendices) and R (B, D, E, G, H, J and K)
No. 5	J, Q (including Appendices) and R (H)
No. 6	F
No. 7	L and M
No. 8	N (and Refrigerated Stores)
No. 9	P, Q (including Appendices) and R (H)

**Rules for Small Ships**

**Rules for Inland Waterways Vessels**

**Rules for Floating Docks**

**Rules for Mobile Offshore Units**

**Rules for Submersibles**

**Rules for Ships for Liquefied Gases**

**Rules for Yachts**

Wood and composite yachts (sailing, auxiliary and full power) (Volume I)  
Steel yachts (Hull construction – advance copies)  
Yachts of the International Rating Classes (Volume III)

**Provisional Rules for Reinforced Plastic Yachts**

**A Guide to Machinery and Electrical Equipment in Yachts**

**Geometric Properties of Rolled Sections and Built Girders**

Volume 1: British and USA sections

Volume 2: Metric sections

Volume 3: Japanese sections

A series of curves giving section moduli and moments of inertia of a wide range of sections used in shipbuilding, in association with varying thicknesses of plating. The areas of sections (without plating) are also given.

**Cargo Handling Gear Code**

**Guidance Notes for Lifts in Ships**

**Freight Container Certification Scheme**

**Refrigerating Machinery Certification Scheme**

**Guidance Notes and Requirements for the Classification of Air Cushion Vehicles**

**Provisional Rules for the Application of Glass Reinforced Plastics to Fishing Craft**

**Approved Welding Consumables for use in Hull Construction**

**List of Approved Fuses**

**List of Type Tested Circuit-breakers**

**List of Type Approved Control and Electrical Equipment (Environmentally Tested)**

**Subscriptions and prices**

Terms of subscription for the Register Books and prices of other publications upon application to Lloyd's Register of Shipping, Garrett House, Manor Royal, Crawley, West Sussex RH10 2QN, England.

## NOTE

In general, SI units of measurement have been adopted in this edition of the Rules, followed by the metric units equivalent where appropriate.

The SI unit, N/mm<sup>2</sup>, has been adopted for pressure and stress, but it is accepted that in practice the non-SI unit 'bar' is used for the calibration of pressure gauges. In certain cases, the measurement of pressure by liquid head may be convenient.

The following conversions are included here for convenience:—

$$1 \text{ N/mm}^2 = 1 \text{ MPa} = 10 \text{ bar} = 10,197 \text{ kgf/cm}^2$$

$$1 \text{ m H}_2\text{O} = 0,009 81 \text{ N/mm}^2 = 0,1 \text{ kgf/cm}^2$$

$$1 \text{ mm Hg} = 0,000 133 \text{ N/mm}^2 = 0,001 36 \text{ kgf/cm}^2$$

# LLOYD'S REGISTER OF SHIPPING



## RULES AND REGULATIONS FOR THE CONSTRUCTION AND CLASSIFICATION OF STEEL SHIPS

1976

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## CHANGES EMBODIED IN PRESENT EDITION OF THE RULES

The following additions and amendments have been adopted by the Committee since the previous (1975) edition of the Rules:—

### Chapter B

#### CLASSIFICATION REGULATIONS

##### Classification

- Section 1. Paragraph 101 has been amended.  
Three new paragraphs (102, 103, 104) have been added.  
Paragraph 107 has been amended.  
A new paragraph (116) has been added.  
A new paragraph (121) has been added.  
Paragraph 123 has been amended.

##### Periodical Surveys

- Section 8. A new paragraph (803) has been added.  
Paragraphs 804 and 805 have been amended.

### Chapter C

#### PERIODICAL SURVEY REGULATIONS

##### Annual and Docking Surveys

- Section 1. Paragraph 102 has been amended.

##### Special Surveys—Hull Requirements

- Section 2. Paragraph 207 has been amended.

### Chapter D

#### HULL CONSTRUCTION

##### General

- Section 1. Paragraphs 125 and 126 have been amended.  
Five new paragraphs (127 to 131) have been added.  
Table D1.1 has been added.  
Figs. D1.2 and D1.3 have been added.

##### Assessment of Longitudinal Strength

- Section 3. Paragraph 317 has been amended.  
Paragraph 320 has been amended.  
Paragraph 322 has been amended.  
Paragraph 345 has been amended.  
Paragraph 347 has been amended.  
Paragraph 349 has been amended.

##### Shell Plating

- Section 5. Paragraph 501 has been amended.  
Paragraph 506 has been amended.  
Paragraph 513 has been amended.

##### Longitudinal Framing

- Section 6. A new paragraph (614) has been added.

##### Transverse Side Framing

- Section 7. Paragraph 726 has been amended.  
Paragraphs 727 to 733 and Fig. D7.4 have been deleted.

##### Deck Beams

- Section 8. Paragraph 803 has been amended.  
Paragraph 812 has been amended.

##### Deck Girders and Transverses

- Section 13. Paragraph 1313 has been amended.

##### End Connections

- Section 16. A new Section has been added (as above).

##### Watertight Bulkheads

- Section 18. The Notes following paragraph 1815 have been amended.  
Fig. D18.4 has been amended.  
Paragraph 1817 has been amended.

##### Rudders

- Section 22. Paragraph 2203 has been amended.  
A new paragraph (2204) has been added.  
Fig. D22.2 has been added.

#### Strengthening for Navigation in Ice (General Service)

- Section 24. Paragraphs 2414 and 2415 have been amended.  
Paragraph 2435. The second sub-paragraph has been deleted.

#### Hatchways and Deck Openings

- Section 26. Paragraph 2601 has been amended.  
A new paragraph (2607) has been added.  
Fig. D26.2 has been added.  
A new paragraph (2608) has been added.  
Paragraphs 2612 and 2613 have been amended.  
A new paragraph (2614) has been added.  
Paragraph 2637 has been amended.

#### Ventilation, Air Pipes and Sounding Pipes

- Section 29. Paragraph 2905 has been amended.

#### Welding

- Section 32. Paragraph 3210 has been amended.  
Paragraph 3211 has been amended.  
Table D32.1 and associated Notes have been revised.  
Tables D32.2, D32.3, D32.4 have been added.

#### FERRIES

- Section 35. Paragraphs 3516 to 3525 have been revised.  
Fig. D35.1 has been added.

#### OIL TANKERS

##### General

- Section 40. Two new paragraphs (4017 and 4018) have been added.

##### Decks and Deck Openings

- Section 42. The heading of this Section has been amended (as above).  
Paragraph 4208 has been deleted.  
Paragraphs 4210 to 4225 have been added.

##### Shell Plating

- Section 43. Paragraph 4301 has been amended.  
Paragraph 4307 has been amended.  
A new paragraph (4311) has been added.

##### Bottom, Side and Deck Longitudinals

- Section 44. Paragraph 4408 has been amended.  
A new paragraph (4409) has been added.

##### Bottom, Side and Deck Transverses

- Section 46. Fig. D46.1 has been deleted.  
Paragraph 4605 has been amended.  
Paragraph 4609 has been amended.

##### Bottom and Deck Girders

- Section 48. Paragraph 4808 has been amended.

#### REQUIREMENTS FOR THE CARRIAGE OF LIQUEFIED GASES

Sections 70, 71, 72 and the above heading have been deleted.

#### DREDGERS, HOPPER DREDGERS, SAND CARRIERS, HOPPER BARGES AND RECLAMATION CRAFT

##### General

- Section 80. A new paragraph (8013) has been added.

##### Hopper and Well Structure

- Section 85. Paragraph 8501 has been amended.

##### Miscellaneous Items

- Section 90. Paragraph 9013 has been deleted.

#### Chapter E

#### PUMPING AND PIPING

##### Liquefied Gases

- Section 12. This Section has been deleted.

Chapter H

MAIN AND AUXILIARY ENGINES AND ASSOCIATED MACHINERY COMPONENTS

PART 2—Gear and Line Shafting and Associated Components for Oil Engine Turbine and Electric Propulsion Installations

- Section 2. Paragraph 222 has been amended.  
Paragraph 229 has been amended.  
Paragraph 230 has been amended.  
Table H2.5 has been amended.  
Tables H2.6 and H2.7 have been added.

General Requirements for Oil Engines and Starting Air Compressors

- Section 6. Three new paragraphs (604 to 606) have been added.  
Paragraph 627 has been deleted.

Chapter J

BOILERS AND OTHER PRESSURE VESSELS

The introductory paragraph has been amended.

General Requirements

- Section 1. Table J1.1 has been amended.

Design

- Section 2. Paragraph 201. In the fifth sub-paragraph (values of c) item (1) has been deleted.  
Fig. J2.16 has been deleted.  
The second sub-paragraph of 249 has been deleted.  
Paragraph 250 has been deleted.

Pressure Vessels for the Carriage of Liquid Petroleum Cases

- Section 7. This Section has been deleted.

Riveted Pressure Vessels

- Section 8. This Section has been deleted.

Chapter K

SPARE GEAR FOR STEAM AND OIL ENGINE MACHINERY INSTALLATIONS

Spare Gear for Ships other than Trawlers or Fishing Vessels

Table K.1. Two new items (8,9) have been added.

Chapter M

ELECTRICAL EQUIPMENT AND ELECTRIC PROPELLING MACHINERY

Rotating Machinery

- Section 4. Paragraphs 426 and 427 have been amended.

Cables

- Section 8. Table M8.1 and associated notes have been amended.  
Paragraph 803 has been amended.  
A second sub-paragraph has been added to paragraph 805.  
Paragraph 806 has been amended.  
In paragraph 808, sub-paragraph (f) has been amended.  
Paragraph 809 has been amended.  
A new paragraph (810) has been added.  
Paragraph 811 has been amended.  
Paragraphs 814 and 815 have been amended.  
Paragraph 821 has been amended.  
Paragraph 829 has been amended.

Special Requirements for Tankers Intended for the Carriage in Bulk of Oil, Liquefied Natural Gas, Liquefied Petroleum Gas and Other Flammable Liquids

- Section 16. The introductory paragraph and Part 2, including paragraphs 1641 to 1649, have been revised.

Chapter P

MATERIALS FOR SHIP CONSTRUCTION

Mild Steel for Hull Structures

- Section 2. Table P2.2 has been amended.

Chapter Q

MATERIALS FOR BOILER, PRESSURE VESSEL AND MACHINERY CONSTRUCTION

Rolled Steel Sections and Bars

- Section 4. In paragraph 401 (a), the final sub-paragraph including its heading has been deleted.  
The heading "ROLLED STEEL BARS (Rivet Quality)" has been deleted.  
Paragraphs 421 to 430 have been deleted.

Appendices to P and Q. A new Appendix 1, "Conversion Tables for use with Chapters P and Q", has been added. The existing Appendix has been made Appendix No. 2, "Lists of Approved Manufacturers and Proving Establishments".



PROVISIONAL RULES AND GUIDANCE NOTES

R(A) Provisional Rules for the use of Methane Gas as Fuel for Propulsion of Methane Tankers  
This Chapter, and the above heading, has been deleted.

R(C) Provisional Rules for the Classification of Nuclear Ships

General

- Section 1. Paragraph 103 has been revised.  
Paragraphs 105 and 106 have been deleted.  
Paragraphs 107 to 113 have been amended.  
Paragraphs 116 to 118 have been amended.  
Paragraphs 120 to 125 have been amended.

Pressure Vessels and their Components

- Section 2. In paragraph 201, the final sub-paragraph has been deleted.  
Paragraph 204 has been amended.  
Paragraph 208 has been amended.  
Paragraph 212 has been amended.  
Paragraph 218 has been amended.  
Paragraph 222 has been amended.  
Paragraph 224 has been amended.

Reactor Engineering

- Section 3. Paragraph 307 has been amended.  
Two new paragraphs (330 and 331) have been added.

Complementary Installation Requirements

- Section 5. A new paragraph (508) has been added.  
In paragraph 512, a second sub-paragraph has been added.  
Paragraph 520 has been amended.

R(J) Provisional Rules for the Classification of Tankers intended for the Carriage of Liquid Chemicals in Bulk

PART 1

Classification

- Section 1. Paragraph 107 has been amended.

PART 3

Pumping and Piping Arrangements

Inert Gas Systems

- Section 16. Paragraph 1601 has been amended.  
Two new paragraphs (1602 and 1603) have been added.  
Paragraphs 1602 and 1603 have been amended.  
Paragraph 1605 has been amended.

PART 4

Electrical Equipment

This Part has been deleted.

PART 5

Tables of Cargoes

This Part has been renumbered PART 4.

FREEBOARD MARKINGS

The heading "ASSIGNMENT OF FREEBOARD" and its associated paragraph have been deleted.  
The three headings for each diagram have been amended.  
The text beneath each diagram has been amended.

A number of alterations of an editorial or minor nature have also been made.

W. T. LEADBETTER,  
*Secretary*



1. The first part of the report deals with the general situation of the country and the progress of the work.

2. The second part of the report deals with the results of the work and the progress of the work.

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# Chapter A

## GENERAL INFORMATION

### Section 1

The Society, which is recognized under the laws of the United Kingdom as a body whose business is conducted for the benefit of the community, was founded in 1760.

It was established for the purpose of obtaining for the use of Merchants, Shipowners and Underwriters a faithful and accurate Classification of Mercantile Shipping and, whilst it still continues to fulfil that purpose, it now also:—

- (a) approves design, surveys and reports on: hovercraft; mercantile and non-mercantile shipping; yachts and small craft; amphibious and land or sea or sea-bed installations, structures, plant, etc.; machinery, apparatus, materials, components, equipment, production methods and processes of all kinds; for the purpose of testing their compliance with plans, specifications, rules, codes of practice, etc., or their fitness for particular requirements;
- (b) acts with delegated authority on behalf of numerous governments in respect of statutory requirements;
- (c) provides other technical inspection and advisory services relating to ships and the maritime industry generally and also in respect of land and sea-based undertakings.

### Section 2

The superintendence of the Society's general affairs is under the direction of the General Committee, which is composed of persons nominated or elected to represent the world community and industry which the Society serves.

1. The General Committee which may at its discretion vary the constitution of such representation, is currently composed of:—

5 members nominated by the General Council of British Shipping as well as the Council's President and Vice-President *ex officio*;

13 members nominated by the London General Shipowners' Society as well as that Society's Chairman and Deputy-Chairman *ex officio*;

9 members nominated by the Committee of Lloyd's as well as the Chairman and a Deputy-Chairman of Lloyd's *ex officio*;

4 members nominated by the Institute of London Underwriters as well as the Institute's Chairman and Deputy-Chairman *ex officio*;

5 members nominated by the Shipbuilders and Repairers National Association;

3 members nominated by the National Association of Marine Enginebuilders;

40 members nominated to represent United Kingdom outports including the representation of the Liverpool and Scottish Committees.

All nominations to be subject to confirmation by the General Committee.



## Chapter A

## LLOYD'S REGISTER OF SHIPPING

40 other members specially elected by the General Committee to include up to 12 International Shipowners and 5 Industrial Services representatives.

Past Chairmen and Deputy-Chairmen of the General Committee and Chairmen of National Committees appointed under Section 5.

2. The General Committee is further empowered to elect as Honorary Members of the General Committee such persons of distinction and eminence as the General Committee shall from time to time think fit.
3. Nominated or *ex officio* members of the General Committee retire annually but are eligible for re-appointment.
4. Elected members of the General Committee retire at the end of 4 years and are eligible for re-election.

UNDER SECTION 3,  
(NOTICE No. 1.)

### Section 3

1. The General Committee has power to:—

Appoint an Executive Board and delegate thereto such of its powers as it may determine.

Appoint Sub-Committees of Classification and determine their powers, duties and functions.

Appoint a National Committee in any country or area to form a liaison between the Society and the local maritime, industrial and commercial communities.

Appoint a Technical Committee and determine its function, powers and duties.

2. The General Committee has exercised its powers and has appointed such Committees.

### Section 4

National Committees are established in the following:—

- (a) Countries:—

Australia

Canada

Denmark

Finland

France

Federal Republic of Germany

Greece

Holland

India

Italy

Japan

New Zealand

Norway

Spain

Sweden

United States of America

- (b) Area:—

East Asia



Section 5

## TECHNICAL COMMITTEE

1. The Technical Committee is at present composed of:—

*Ex officio—*

	TOTAL
The Chairman of Lloyd's Register ... ..	1
The Deputy-Chairman and Chairman of the Sub-Committees of Classification of Lloyd's Register ...	1
The Deputy-Chairman and Treasurer of Lloyd's Register ... ..	1

*Nominated by—*

The General Committee of Lloyd's Register ... ..	12
The Royal Institution of Naval Architects ... ..	2
The North-East Coast Institution of Engineers and Shipbuilders ... ..	2
The Institution of Engineers and Shipbuilders in Scotland ... ..	2
The Shipbuilders and Repairers National Association ... ..	7
The National Association of Marine Enginebuilders ... ..	3
The Institute of Marine Engineers ... ..	2
The British Internal Combustion Engine Manufacturers' Association ... ..	1
The Society of Consulting Marine Engineers and Ship Surveyors ... ..	1
The Metals Society ... ..	1
The British Steel Corporation ... ..	1
The British Independent Steel Producers' Association ... ..	1
The Honourable Company of Master Mariners ... ..	1
The Institution of Electrical Engineers ... ..	1
The British Electrical and Allied Manufacturers' Association ... ..	1
The Technical Committee ... ..	7
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All nominations are subject to confirmation by the General Committee.

In addition to the foregoing:—

- (a) Each National Committee may appoint a representative to attend meetings of the Technical Committee.
  - (b) Further persons may, with the consent of the General Committee, be co-opted to serve on the Technical Committee.
2. The function of the Technical Committee is to consider any technical problems connected with the Society's business and any proposed alterations in the existing Rules, or to frame new Rules, for the classification, survey and building of ships (hull and machinery).
  3. The term of office of all Members is 4 years, one-fourth retiring each year, the Members so retiring being eligible for re-nomination for a second term.

4. Meetings of the Technical Committee are convened as often and at such times and places as is necessary, but there are to be at least two meetings in each year.
5. Any proposal of the Technical Committee involving any amendment of, or addition to, the Rules for the classification, survey or building of ships (hull and machinery) is referred to the General Committee and may be finally approved at the next following meeting of the Executive Board if the General Committee so direct.
6. The Technical Committee is empowered to:—
  - (a) appoint Panels of the Committee; and
  - (b) co-opt to the main Committee, or to such panels, representatives of any organization or industry or private individuals for the purpose of considering any particular problem.

### Section 6

The General Committee has power to:—

“adopt, and publish as deemed necessary, Rules relating to the classification of ships”;

and has in relation thereto provided the following:—

1. Except in the case of a special directive by the Committee, no new Rule or alteration in any existing Rule materially affecting classification is to be applied compulsorily within 6 months of its adoption, nor after the approval of the original midship section. When it is desired to use existing approved ship or machinery plans for a new contract, written application is to be made to the Committee.
2. All reports of survey are to be made by the Surveyors according to the form prescribed, and submitted for the consideration of the General Committee, or of the Sub-Committees of Classification, but the character assigned by the latter is to be subject to confirmation by the General Committee or by the Chairman acting on behalf of the General Committee.
3. The reports of the Surveyors (and all documents and proceedings relating to the classification of ships) are to be carefully preserved and shall, subject to the approval, in his absolute discretion, of the Chairman or one of the Deputy-Chairmen, be open to the inspection of the Owner and of any other person authorized in writing by the Owner. Copies of reports will, subject to the approval of one of the Chairmen be supplied to Owners, or their representatives, on application.

### Section 7

The employees of the Society are not permitted (without the special sanction of the General Committee) to receive any fee, gratuity, or reward whatsoever, for their own use or benefit, for any service performed by them in their capacity as employees of the Society on pain of instant dismissal.

### Section 8

The General Committee has power to:—

- (a) determine the amounts to be charged for the services provided by the Society or for any of its publications;
- (b) withhold or, if already granted, withdraw the class of any ship, (or withhold any certificate or report in any other case), in the event of non-payment of any fee on account of any ship.



Section 9

The Committees of the Society use their best endeavours to ensure that the functions of the Society are properly executed, but it is to be understood that neither the Society nor any Member of any of its Committees, nor any of its Officers, Servants or Surveyors is under any circumstances whatever to be held responsible or liable for any inaccuracy in any report or certificate issued by the Society or its Surveyors, or in any entry in the *Register Book* or other publication of the Society, or for any act or omission, default or negligence of any of its Committees or any Member thereof, or of the Surveyors, or other Officers, Servants or Agents of the Society.

Page 1

THE UNITED STATES OF AMERICA

1914

1. That the United States of America, in conformity with the provisions of the Act of March 3, 1907, entitled "An Act to amend the Act of March 3, 1907, entitled 'An Act to provide for the collection of customs duties on imports and exports of merchandise', and for other purposes," and for other purposes, do hereby certify that the following is a true and correct copy of the original of the same as the same appears in the records of the Department of the Treasury:

2. That the said Act of March 3, 1907, is hereby certified to be a true and correct copy of the original of the same as the same appears in the records of the Department of the Treasury:

Page 2

3. That the said Act of March 3, 1907, is hereby certified to be a true and correct copy of the original of the same as the same appears in the records of the Department of the Treasury:

4. That the said Act of March 3, 1907, is hereby certified to be a true and correct copy of the original of the same as the same appears in the records of the Department of the Treasury:

5. That the said Act of March 3, 1907, is hereby certified to be a true and correct copy of the original of the same as the same appears in the records of the Department of the Treasury:

6. That the said Act of March 3, 1907, is hereby certified to be a true and correct copy of the original of the same as the same appears in the records of the Department of the Treasury:

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7. That the said Act of March 3, 1907, is hereby certified to be a true and correct copy of the original of the same as the same appears in the records of the Department of the Treasury:

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8. That the said Act of March 3, 1907, is hereby certified to be a true and correct copy of the original of the same as the same appears in the records of the Department of the Treasury:

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## Chapter B

# CLASSIFICATION REGULATIONS

### Section 1

#### CLASSIFICATION

##### General

**101** Steel ships built in accordance with the Society's Rules and Regulations, or with alternative arrangements equivalent thereto (*see* B 501), will be assigned a class in the *Register Book* and will continue to be classed so long as they are found, upon examination at the prescribed annual and other periodical surveys, to be maintained in a fit and efficient condition and in accordance with the requirements of the Rules.

The Committee, in addition to requiring compliance with the Society's Rules, may require to be satisfied that very small ships, or ships of special type, are suitable for the geographical limits of service contemplated.

Loading conditions and any other preparations required to permit a ship with the notation "restricted service" or "for restricted service" to undertake a sea-going voyage, either from port of building to service area, or from one service area to another, are to be in accordance with instructions agreed by the Society, in the case of "restricted service" ships at the time of plan approval or, in the case of "for restricted service" ships, prior to the voyage.

Classification will be conditional upon compliance with the Society's requirements in respect of both hull and machinery (i.e. main and auxiliary engines including torsional vibration characteristics, boilers, essential appliances, pumping arrangements and electrical equipment).

The Rules are framed on the understanding that ships will be properly loaded and handled; they do not, unless stated or implied in the class notation, provide for special distributions or concentrations of loading. The Committee may also require additional strengthening to be fitted in any ship which, in their opinion, may otherwise be subjected to severe stresses due to particular features in her design or when it is desired to make provision for exceptional loaded or ballasted conditions. Particulars are to be submitted for consideration.

##### Advisory Services

**102** The Rules do not cover certain technical characteristics such as stability, trim, hull vibration, etc. The Committee cannot assume responsibility for these matters but is willing to advise upon them on request.

**Draught and Stability Requirements for Specialized Ships**

**103** In the cases of offshore supply ships, offshore tug/supply ships, dredgers, hopper dredgers, sand carriers, hopper barges or reclamation craft, each ship proceeding to sea is to comply with the draught and stability requirements of the National Authority and is to have on board sufficient stability data to enable it to be properly loaded and handled or, where appropriate, for the ship to be properly towed. In the case of an unmanned ship under tow, the data is to be made available to the tugmaster. This data is to take full account of any special distribution or concentration of loading for which the particular ship may be designed (*see also* D 8005, D 8008 (j) and D 9002).

**Statutory Surveys and Certification**

**104** The Committee, when authorized, will act on behalf of Governments in respect of National and International statutory safety and other requirements for passenger and cargo ships.

**Definitions**

**105**

Clear water. Water having sufficient depth to permit the normal development of wind generated waves.

Fetch. The extent of clear water across which a wind has blown before reaching the ship.

Sheltered water. Water where the fetch is 6 nautical miles or less.

Reasonable weather. For the purpose of assessing scantlings in these Rules, reasonable weather is assumed to exclude winds exceeding Beaufort force 6 associated with sea states resulting in green water being frequently taken on board the ship's deck. However, it is realized that this is largely a matter of judgment and good seamanship and can vary for particular ships.

Restricted Service. Service in estuaries, harbours and/or adjacent waters and also outside sheltered water but only for short distances (generally less than 15 nautical miles) and in reasonable weather.

These limitations will also appear in the key to the *Register Book*.

For Restricted Service. Service within geographical limits which will be indicated in the notation affixed to the character of class in the *Register Book*.

**Character of Classification and Class Notations**

**106** Class 100A1. This class will be assigned to sea-going ships built in accordance with the Society's Rules and Regulations for the draught required.

**107** Class 100A1 oil tanker. This class will be assigned to sea-going tankers intended to carry oil in bulk and built in accordance with the Society's Rules and Regulations for the draught required.

Where the scantlings and arrangements have been approved by the Committee for the carriage of oil having a flash point of 60°C or above (closed cup test), or other liquid cargoes in bulk, the class notation affixed to the character will be suitably modified to show the nature of the cargo.

Where a ship intended for the carriage of oil in bulk having a flash point below 60°C (closed cup test) is fitted with an inert gas system, the system is to be arranged, installed and tested in accordance with the Society's Rules and Regulations.

The notation "IGS" will be entered in the *Register Book*, but the notation may be omitted at the Owner's request, except in the following cases:—

- (a) where the inert gas system forms part of the corrosion control system, or
- (b) where the pump room is acting as a cofferdam, and a bulkhead which does not form part of the boundary of a cargo tank or an oil fuel bunker is of watertight bulkhead scantlings in accordance with D 5005.

**108** Class 100A1 liquefied gas carrier, type of gas(es) in independent tanks, maximum vapour pressure, minimum temperature and where necessary maximum temperature (to be specified). This class will be assigned to sea-going ships specially designed for the carriage of liquefied petroleum, natural or other gases and built in accordance with the Society's Rules and Regulations for the draught required.

**109** Class 100A1 ore carrier. This class will be assigned to sea-going ships specially designed for the carriage of ore and built in accordance with the Society's Rules and Regulations for the draught required.



110 Class 100A1 ore or oil carrier. This class will be assigned to sea-going ships specially designed for the carriage of ore or oil and built in accordance with the Society's Rules and Regulations for the draught required. *See also 125.*

111 Class 100A1 trawler, 100A1 stern trawler, 100A1 fishing vessel. These classes will be assigned to ships built in accordance with the Society's Rules and Regulations for such ships. For the purpose of this Regulation, a fishing vessel is a ship used for fishing operations but not equipped for trawling.

112 Class 100A1 tug. This class will be assigned to all sea-going tugs built in accordance with the Society's Rules and Regulations for such ships.

113 Class 100A1 icebreaker. This class will be assigned to sea-going ships specially designed for icebreaking duties, and built in accordance with those Sections of the Society's Rules and Regulations appropriate to such ships, and other special requirements as may be approved by the Committee for the proposed service.

114 Class 100A1 barge. This class will be assigned to non-self-propelled, manned or unmanned sea-going ships carrying general dry cargo in cargo holds and built in accordance with the Society's Rules and Regulations for such ships for the draught required.

115 Class 100A1 pontoon. This class will be assigned to non-self-propelled, manned or unmanned sea-going ships designed specifically for the carriage of non-perishable cargo on deck and built in accordance with the Society's Rules and Regulations for such ships for the draught required.

116 Class 100A1 offshore supply ship.

Class 100A1 offshore tug/supply ship.

These classes will be assigned to sea-going ships specially designed and constructed for the carriage of specialized stores and cargoes to mobile offshore units and other offshore installations (and, in the case of offshore tug/supply ships, to perform the duties of a tug), and which are built in accordance with the Society's Rules and Regulations for the draught required.

117 Class 100A1 oil barge. This class will be assigned to non-self-propelled, manned or unmanned sea-going ships intended to carry oil in bulk and built in accordance with the Society's Rules and Regulations for such ships for the draught required.

Where the scantlings and arrangements have been approved by the Committee for the carriage of oil having a flash point of 60°C or above (closed cup test), or for other liquid cargoes in bulk, the class notation affixed to the character will be suitably modified to show the nature of the cargo (e.g. water barge, molasses barge, etc.).

118 Class 100A1 ferry for restricted service. This class will be assigned to sea-going ships intended to operate ferry services within specific limits and built in accordance with the Society's Rules and Regulations and having the reduced scantlings for the draught required.

The class notation affixed to the character will indicate the geographical limits of the service for which the class is assigned.

119 For restricted service. When sea-going ships, referred to in 106 to 113, are intended to operate within specific limits and have been built in accordance with the Society's Regulations, and the scantlings, arrangements and equipment approved by the Committee for such service, the class notation affixed to the character in the *Register Book* will indicate the geographical limits of the service.

For special purposes. When sea-going ships intended for special purposes, other than those defined in this Section, have been built in accordance with the Society's Regulations and the scantlings, arrangements and equipment approved by the Committee for such ships, an appropriate descriptive notation will be inserted in the *Register Book*.

120 Class 100A1 barge, restricted service

Class 100A1 pontoon, restricted service

Class 100A1 oil barge, restricted service.

These classes will be assigned to ships built in accordance with the Society's Rules and Regulations and having the reduced scantlings permitted by the Rules for the draughts required and which are intended to operate a restricted service as defined in 105.



121 Class 100A1 ship-borne barge, restricted service. This class will be assigned to ships which:—

- (a) are built in accordance with the Society's Rules and Regulations,
- (b) have suitable arrangements consistent with the regular carriage of the barge on board a larger ship,
- (c) have scantlings not less than the reduced scantlings permitted by the Rules for ships classed 100A1 barge, restricted service,
- (d) are intended to operate afloat only in a restricted service as defined in 105.

122 Class A1 for restricted service. This class will be assigned to ships intended to trade only within specially sheltered waters, such as harbours, rivers or estuaries, provided the scantlings, arrangements and equipment are approved by the Committee as suitable for such service. The class notation affixed to the character will indicate the geographical limits for which the ship has been approved.

123 Heavy Cargoes (i.e. ore, etc.). When the scantlings and arrangements have been approved for the carriage of such cargoes a class notation "Strengthened for heavy cargoes" will be entered in the *Register Book*.

Where, in association with the carriage of heavy cargoes, certain holds are permitted to be empty with the ship in the loaded condition, a further notation will be entered in the *Register Book*, thus: "Holds . . . may be empty".

124 Alternative carriage of oil cargoes. Where, in a ship designed for the carriage of bulk dry cargoes, the scantlings and arrangements have also been approved for the carriage of bulk oil cargoes, the additional notation "or oil cargoes" will be entered in the *Register Book*. See also 125.

125 The notations "ore or oil carrier" and "or oil cargoes" prohibit the simultaneous carriage of ore and oil. This does not preclude oil being retained in slop tanks while carrying ore provided these tanks comply with the requirements of the Rules. Gas freeing, or inerting and isolating by approved arrangements of the remaining tanks and holds before loading ore is to be the responsibility of the Owners and in accordance with National or Port Authority requirements.

Similar restrictions may be applied to the association of oil with certain other cargoes.

126 Special cargoes. When the scantlings and arrangements have been approved for cargoes of a special nature an appropriate class notation will be entered in the *Register Book*.

127 Special features. When a special feature in the design or construction of a ship or its machinery has been approved, an appropriate class notation, e.g. "movable decks", may be entered in the *Register Book*.

128 Corrosion control. Where an approved method of corrosion control is fitted and an appropriate reduction in scantlings has been permitted, the notation "(cc)", or "(cc) crude oil—defined ballasting", as appropriate, will be entered in the *Register Book*.

129 Strengthening for navigation in ice. Where an ice class notation is desired, additional strengthening is to be fitted in accordance with the requirements given in the Rules. Details of the requirements are given in the Rules for the following classes of ice strengthening:—

- (a) For general service:

Ice Class 1\* strengthening is for ships intended to navigate in extreme ice conditions.

Ice Class 1 strengthening is for ships intended to navigate in severe ice conditions.

Ice Class 2 strengthening is for ships intended to navigate in intermediate ice conditions.

Ice Class 3 strengthening is for ships intended to navigate in light ice conditions.

- (b) Primarily for trading in the northern Baltic in winter time:

Ice Class IA Super strengthening is for ships intended to navigate in extreme ice conditions.

Ice Class IA strengthening is for ships intended to navigate in severe ice conditions.

Ice Class IB strengthening is for ships intended to navigate in medium ice conditions.

Ice Class IC strengthening is for ships intended to navigate in light ice conditions.

These requirements for classes are equivalent to those for the corresponding notations in Annex I of the "Finnish-Swedish Ice Class Rules 1971".

It is the responsibility of the Owner to determine which notation is most suitable for his requirements.



SPECIAL REQUIREMENTS FOR DREDGERS, HOPPER DREDGERS, SAND CARRIERS,  
HOPPER BARGES AND RECLAMATION CRAFT**Definitions**

**130 Dredger.** A ship designed to operate wholly or generally for the purpose of raising mud, silt, gravel, clay or similar substances, general rubbish or ore, minerals, etc., from the bed of the sea, rivers, lakes, canals, or harbours, etc.

**Reclamation Craft.** Reclamation ships, etc., which work in a manner similar to suction dredgers but draw their spoil from hopper barges (or floating pipe lines connected to a dredger) and discharge it ashore.

**Hopper.** A hold or other space designed to carry dredged spoil and also arranged to enable such spoil to be discharged through doors or valves in the bottom of the ship.

Spaces arranged to be unloaded by means of conveyor belts, suction pipes or similar gear are not to be regarded as hoppers unless adequate bottom doors or valves are also fitted.

**Hopper Dredger.** A dredger constructed such that the dredged material may be stored or transported in one or more hoppers within the ship.

**Sand Carrier.** A dredger, other than a hopper dredger, constructed such that the dredged material, which need not be restricted to sand, may be stored or transported in suitably designed holds or similar spaces within the ship.

**NOTE.** Diamond dredgers and similar ships with on board processing plant will not normally be regarded as sand carriers unless the weight of ore and spoil on board during processing operations exceeds 25 per cent of the ship's light-weight displacement.

**Hopper Barge.** A ship which need not be self-propelled designed to carry bulk cargo in hoppers within the ship.

**Character of Classification and Class Notation**

**131** Class 100A1 dredger

Class 100A1 hopper dredger

Class 100A1 sand carrier

Class 100A1 hopper barge

Class 100A1 reclamation craft.

These classes will be assigned to ships built in accordance with the Society's Rules and Regulations for the draughts required, and which are intended to make sea-going voyages either as part of their work or while transferring from one work area to another as part of their normal operations.

Bucket dredgers will not be assigned this character of classification.

Sand carriers will not normally be assigned this character of classification unless spoil spaces are provided with adequate hatch covers.

**132** Class 100A1 dredger, restricted service

Class 100A1 hopper dredger, restricted service

Class 100A1 sand carrier, restricted service

Class 100A1 hopper barge, restricted service

Class 100A1 reclamation craft, restricted service.

These classes will be assigned to ships built in accordance with the Society's Rules and Regulations and having the reduced scantlings permitted by the Rules for the draughts required and which are intended to operate a restricted service as defined in 105.

**133** Class A1 dredger, protected waters service

Class A1 hopper dredger, protected waters service

Class A1 sand carrier, protected waters service

Class A1 hopper barge, protected waters service

Class A1 reclamation craft, protected waters service.

These classes will be assigned to ships built in accordance with the Society's Rules and Regulations for the draughts required, and which are intended to operate only within protected waters such as harbours, rivers, small lakes and sheltered estuaries.

The above limitations, applicable to a ship classed "protected waters service", will also appear in the key to the *Register Book*.

**Descriptive Note**

134 An appropriate descriptive note will be entered in Column 6 of the *Register Book* indicating the type of dredger, sand carrier or hopper barge, for example:—

Trailing Suction Dredger  
Cutter Suction Dredger  
Bucket Dredger  
Grab Dredger  
Dipper Dredger  
Self-discharging Sand Dredger.

**Section 2****EQUIPMENT**

201 The figure 1 in the character of classification assigned to a ship indicates that her equipment of anchors, chain cables and hawsers is in good and efficient condition and in the cases of ships not classed for a special or restricted service, in accordance with the requirements of the Rules. In the case of ships classed for a special or restricted service, the figure 1 indicates that the equipment has been approved by the Committee as suitable for the particular service.

202 When the equipment of a ship is not supplied or maintained in accordance with the requirements of the Rules but is considered by the Committee to be acceptable for the particular service, the Committee may agree to the figure 1 being omitted and a line inserted after the character, thus, 100A—. In cases where the equipment is found to be seriously deficient in quality or quantity, the class of the ship will be liable to be withheld from the *Register Book*. Special consideration will be given to ships intended to be classed for which, by reason of their particular purpose or service, normal equipment may be unnecessary. In such cases the figure 1 may be omitted from the character of classification, thus: 100A.

**Special Requirements for Dredgers, Hopper Dredgers, Sand Carriers, Hopper Barges and Reclamation Craft**

203 The figure 1 in the character of classification assigned to a ship indicates that her equipment of anchors, chain cables and hawsers is in good and efficient condition and in accordance with the requirements of the Rules. In the case of ships classed for restricted or protected waters service, the figure 1 indicates that the anchoring and mooring equipment has been approved by the Committee as suitable for the particular service.

**Section 3****MACHINERY**

301 (a) The machinery, as defined in B 101, is to be constructed and installed on board ship in accordance with the Society's Rules and Regulations. On satisfactory completion of trials, an appropriate class notation will be assigned in the *Register Book*, thus: "LMC" (Lloyd's Machinery Certificate).

(b) Where arrangements are such that essential machinery can be operated by remote and/or automatic control equipment, the control equipment is to be arranged, installed and tested in accordance with the Society's Rules and Regulations.

(c) When arrangements are such that the ship can be operated with the machinery spaces unattended (*see* Chapter L) a notation "UMS" will be assigned in the *Register Book* unless the Owner expresses a wish to the contrary. Non-compliance with the relative sections of Chapter L will not affect the LMC notation since the Society's Rules require that the essential machinery can be operated satisfactorily with the control system(s) out of action.

**Section 4****MATERIALS**

401 The materials used in the construction of hulls and machinery intended for classification, or in the repair of ships already classed, are to be of good quality and free from defects and are to be tested in accordance with the requirements of Chapters P and Q. The steel is to be manufactured by an approved process at works recognized by the Committee. Alternatively, tests to the satisfaction of the Committee will be required to demonstrate the suitability of the steel.



**Section 5****EQUIVALENT ARRANGEMENTS**

501 Alternative arrangements will be permitted, provided they are considered by the Committee to be equivalent to the Society's requirements.

**Section 6****NEW CONSTRUCTION****Submission of Plans**

601 When it is intended to build a ship for classification with the Society, constructional plans and particulars of the hull, equipment and machinery (see B 101), as detailed in the Rules, are to be submitted through the local Surveyors for the approval of the Committee before the work is commenced.

Any subsequent modifications or additions to the scantlings, arrangements or equipment shown on the approved plans are also to be submitted for approval.

**Use of Approved Items of Machinery**

602 Machinery may incorporate items which have been type tested and approved by the Committee.

Constructional plans and particulars of approved items need not be included in submissions made in accordance with 601.

**Novel Forms of Construction**

603 Where the proposed construction of any part of the hull or machinery is novel in design, or involves the use of unusual material, or where experience, in the opinion of the Committee, has not sufficiently justified the principle or mode of application involved, special tests or examinations before and during service may be required. A suitable notation will be inserted in the *Register Book* when the Committee consider this necessary.

**Special Survey during Construction**

604 New ships intended for classification are to be built under the Society's Special Survey and when classed will be entitled to the distinguishing mark  $\boxtimes$  inserted before the character in the *Register Book*, thus: " $\boxtimes$ 100A1".

From the commencement of the work until the completion of the ship, the Surveyors are to examine the materials, workmanship and arrangements. Any items not in accordance with the Rules or the approved plans, or any material, workmanship or arrangement found to be unsatisfactory are to be rectified.

New machinery for ships classed or intended for classification is to be constructed under the Society's Special Survey, and on completion will be entitled to the distinguishing mark  $\boxtimes$  inserted before the machinery class notation in the *Register Book*, thus: " $\boxtimes$ LMC".

The Special Survey during construction of the machinery shall relate to the period from the commencement of the work until the final test under working conditions. Any items not in accordance with the Rules or the approved plans, or any material, workmanship or arrangement found to be unsatisfactory are to be rectified.

The Committee will consider proposals for the installation of some important parts constructed under the survey of a recognized Classification Society where such construction is considered equivalent to the Society's requirements. Where permitted, such machinery will be entitled to the distinguishing mark  $\boxtimes$  in the *Register Book*, thus: " $\boxtimes$ LMC".

**Date of Build**

605 The date of completion of the Special Survey during Construction of ships built under the Society's inspection will normally be taken as the date of build to be entered in the *Register Book*. If the period between launching and completion or commissioning is, for any reason, unduly prolonged, the dates of launching and completion or commissioning may be separately indicated in the *Register Book*.

When a ship upon completion is not immediately put into commission, but is laid up for a period, the Committee, upon application by the Owner, prior to the ship proceeding to sea, may direct an examination of the ship to be made in drydock by the Society's Surveyors. If, as the result of such survey, the hull and machinery be reported in all respects free from deterioration, the subsequent Special Survey and Complete Survey of the machinery will date from the time of such examination.

### Section 7

#### CLASSIFICATION OF SHIPS NOT BUILT UNDER SURVEY

701 The requirements of the Committee for the classification of ships which have not been built under the Society's survey are set forth in C 13.

### Section 8

#### PERIODICAL SURVEYS

##### Annual Surveys

801 All steel ships are to be surveyed at intervals of approximately one year, in accordance with the requirements set forth in C 1.

##### Docking Surveys

802 Owners should notify the Society whenever a ship can be examined in drydock or on a slipway. It is desirable that ships should be examined in drydock at intervals of about 12 months; the maximum interval is to be 2 years, except that where a suitable high resistance paint is applied to the underwater portion of the hull and an approved automatic system of impressed current external cathodic protection is fitted, this maximum interval may be extended to about 2½ years at the discretion of the Committee.

Attention should also be given to any relevant statutory requirements of the National Authority of the country in which the ship is registered.

This regulation is not applicable to ships operating in fresh water or to certain non-self-propelled craft; the interval between drydockings for these ships may be greater than is stated above.

The date of the last examination in drydock or on a slipway will be recorded in the *Supplement to the Register Book*.

##### Intermediate Surveys

803 As an alternative to Annual Surveys and Docking Surveys, ships classed 100A1 ship-borne barge may be subjected to Intermediate Surveys. These surveys become due 30 months after the previous Special Survey. The survey is to be in accordance with the requirements set forth in C 1 as applicable. Intermediate Surveys are to be completed within 3 months of the due date.

##### In-water Surveys

804 Survey requirements are set forth in Chapter R(K). The date of the last in-water survey will be recorded in the *Supplement to the Register Book*, preceded by the notation "IWS".

##### Special Surveys

805 All steel ships classed with the Society are also to be subjected to Special Surveys in accordance with the requirements set forth in C 2 to C 9. These surveys become due at 4-yearly intervals, the first one 4 years from the date of build or date of Special Survey for Classification, and thereafter 4 years from the date of the previous Special Survey.

Where, on ship-borne barges, Intermediate Surveys are permitted as an alternative to Annual and Docking Surveys, Special Surveys become due 5 years after the previous Special Survey.



**Period Allowed for Completion of Special Surveys**

806 When it is inconvenient for Owners to fulfil all the requirements of a Special Survey at its due date, the Committee will be prepared to consider its postponement, either wholly or in part, provided that the Society's Surveyors are afforded an opportunity, about the due date, of assessing the general condition of the hull. For this purpose the Committee will normally call for a general examination of the ship, including drydocking, of sufficient extent to be assured that her condition is satisfactory for the period of grace desired, which is not to exceed 12 months from the due date.

Special Surveys which are commenced prior to their due date are not to extend over a period greater than 12 months, except with the prior approval of the Committee, who will be prepared to consider suitable arrangements for carrying out Special Surveys over an extended period in the case of ships engaged on a regular schedule.

Special Surveys on ship-borne barges are to be completed within 3 months of the due date.

**Record of Special Surveys**

807 Ships which have satisfactorily passed a Special Survey will have a record entered in the *Supplement to the Register Book* indicating the date. Where a Special Survey is not completely carried out at one time, the date recorded in the *Supplement* will be the date at which the principal part of the requirements is complied with. Records of Special Survey will not be assigned until the Society's requirements for machinery surveys detailed in 809 or 810 are satisfactorily completed.

**Continuous Surveys**

808 When, at the request of Owners, it has been agreed by the Committee that the complete survey of the hull may be carried out on the Continuous Survey basis, all compartments of the hull should be opened for survey and testing in rotation with an interval of 5 years between consecutive examinations of each part.

If the examination during Continuous Survey reveals any defects, further parts are to be opened up and examined as considered necessary by the Surveyor.

Ships which have satisfactorily completed the cycle will have a record entered in the *Supplement to the Register Book* indicating the date of completion.

**Surveys of Machinery**

809 Machinery, as defined in B 101, is to be submitted to the surveys described in C 6 to C 12.

Complete Surveys of machinery become due at 4-yearly intervals, the first one 4 years from the date of build or date of first Classification as recorded in the *Register Book*, and thereafter 4 years from the date of the previous Complete Survey. Whether or not Complete Surveys are commenced prior to their due date, they are not to extend over a period greater than 12 months without the approval of the Committee. On satisfactory completion of a survey an appropriate record will be made in the *Supplement to the Register Book*. When a Complete Survey is not carried out at one time the date recorded in the *Supplement* will be that by which the major portion of the survey has been held.

If it is found desirable that any part of the machinery should be again examined before the due date of the next survey, a certificate for a limited period will be granted in accordance with the nature of the case.

When it is inconvenient for Owners to fulfil all the requirements of a Complete Survey at its due date, the Committee will be prepared to consider its postponement, either wholly or in part, provided that the Society's Surveyors are afforded an opportunity, about the due date, of assessing the general condition of the machinery. For this purpose the Committee will normally require a general examination to be made of sufficient extent to assure them that the condition of the machinery is satisfactory for the period of grace desired, which is not to exceed 12 months from the due date. This general examination will usually include any item which has not been surveyed for 5 years, together with any item in respect of which the 5-year interval would otherwise be exceeded during the period of postponement.

**Continuous Surveys of Machinery**

810 When, at the request of Owners, it has been agreed by the Committee that the complete survey of the machinery may be carried out on the Continuous Survey basis, the various items of machinery should be opened for survey in rotation, so far as practicable, to ensure that the interval between consecutive examinations of each item will not exceed 5 years. In general, approximately one-fifth of the machinery should be examined each year.



In such cases a record indicating the date of completion of the Continuous Survey cycle will be made in the *Supplement to the Register Book*.

If any examination during Continuous Survey reveals defects, further parts are to be opened up and examined as considered necessary by the Surveyor and the defects are to be made good to his satisfaction.

Upon application by Owners the Committee may agree to an arrangement whereby, subject to certain conditions, some items of machinery may be examined by the Chief Engineer of the ship at ports where the Society is not represented or, where practicable, at sea, and a limited confirmatory survey carried out at the next port of call where an Exclusive Surveyor is available. Particulars of the arrangement may be obtained from the Society's Head Office.

#### Boiler, Steam Pipes and Screwshaft Surveys

811 Boiler Surveys, examination of Steam Pipes and Screwshaft Surveys should be carried out as set forth in C 10, C 11 and C 12. On satisfactory completion, appropriate records will be made in the *Supplement to the Register Book*.

#### Survey of Inert Gas Systems

812 Where an inert gas system is fitted on board ships intended for the carriage of oil in bulk having a flash point below 60°C (closed cup test) and with the notation "IGS", the system is to be surveyed at intervals not exceeding 2 years. Survey requirements are set forth in E 11.

### Section 9

#### REFRIGERATION

901 On application from Owners, refrigerated cargo installations which comply with Chapter N of the Rules and are favourably reported on by the Surveyors will be assigned an appropriate class in accordance with N 1. Certificates will be issued and the class notation, together with the particulars of the installation, will be entered in the *Supplement*.

902 The class assigned will be retained provided the installation is found to be in a good and efficient condition at the Periodical, Loading Port and other Surveys set forth in N 8.

903 The paragraphs in B 14 regarding Withdrawal of Class and in B 15 regarding Reclassification, apply also to Refrigerated Cargo Installations.

### Section 10

#### REPAIRS AND ALTERATIONS

##### Repairs

1001 All repairs to hull, equipment and machinery which may be required in order that a ship may retain her class are to be carried out under the inspection of, and to the satisfaction of, the Society's Surveyors. When repairs are effected at a port where there is no Surveyor to this Society, the ship is to be surveyed by one of the Society's Surveyors at the earliest opportunity.

1002 When at any survey the Surveyors consider repairs to be necessary, either as a result of damage, or of wear and tear, they will communicate their recommendations at once to the Owners, or their representative, and if compliance therewith cannot be arranged, immediate notification will be given by the Surveyors to the Committee.

1003 If a ship which is classed with the Society is damaged to such an extent as to necessitate towage outside port limits, it shall be the Owner's responsibility to notify Lloyd's Register at the first practicable opportunity.

##### Alterations

1004 Plans and particulars of any proposed alterations to the approved scantlings and arrangements of hull, equipment, or machinery, are to be submitted for approval and such alterations are to be carried out under the inspection of, and to the satisfaction of, the Society's Surveyors.



**Section 11****APPEAL FROM SURVEYORS' RECOMMENDATIONS**

1101 If the recommendations of the Society's Surveyors are considered in any case to be unnecessary or unreasonable, appeal may be made to the Committee, who may direct a special examination to be held.

**Section 12****NOTICE OF SURVEYS**

1201 It is the responsibility of Owners to ensure that all surveys necessary for the maintenance of class are carried out at the proper time under the supervision of the Society's Surveyors.

The Society will give timely notice to Owners about forthcoming surveys by means of a letter or a quarterly computer print-out. The non-receipt of such notice does not absolve Owners from their responsibility to comply with the Society's survey requirements for maintenance of class.

**Section 13****CERTIFICATES**

1301 When the required reports on completion of the Special Surveys of new ships, or of existing ships submitted for classification, have been received from the Surveyors and approved by the Committee, certificates of first entry of classification, signed by the Chairman, Deputy-Chairman and Treasurer, or Deputy-Chairman and Chairman of the Sub-Committees of Classification, and countersigned by the Secretary, will be issued to Builders or Owners.

1302 Certificates of class maintenance in respect of completed periodical surveys of hull and machinery will also be issued to Owners on application.

1303 The Society's Surveyors are permitted to issue provisional certificates to enable a ship, classed with the Society, to proceed on her voyage provided that, in their opinion, she is in a fit and efficient condition. Such certificates will embody the Surveyor's recommendations for continuance of class, but in all cases are subject to confirmation by the Committee.

**Section 14****WITHDRAWAL OF CLASS****Owners' Requests**

1401 When the class of a ship, for which the Regulations as regards surveys on hull, equipment and machinery have been complied with, is withdrawn by the Committee in consequence of a request from the Owners, the notation "Class withdrawn at Owners' request" (with date) will be made in the *Supplement* and the notation "LR class withdrawn—Owners' request" (with date) will be made in the next reprint of the *Register Book*. After one year the notation will be altered to "Classed LR until" (with date).

**Non-compliance with the Regulations**

1402 When the Regulations as regards surveys on the hull or equipment or machinery have not been complied with and the ship thereby is not entitled to retain class, the class will be withdrawn and the notation "Class withdrawn" (with date) will be made in the *Supplement* and the notation "LR class withdrawn" (with date) will be made in the next reprint of the *Register Book*. After one year the notation will be altered to "Classed LR until" (with date).

**Reported Defects**

1403 When it is found from reported defects in the hull or equipment or machinery that a ship is not entitled to retain class in the *Register Book*, and the Owners fail to repair such defects in accordance with the Society's require-

ments, the class will be withdrawn and the notation "Class withdrawn—Reported defects" (with date) will be made in the *Supplement* and the notation "LR class withdrawn—Reported defects" (with date) will be made in the next reprint of the *Register Book*. After one year the notation will be altered to "Classed LR until" (with date).

#### **Infringement of Freeboard Conditions**

**1404** Where any ship proceeds to sea with a less freeboard than that approved by the Committee, or where the freeboard marks are placed higher on the ship's sides than the position assigned or approved by the Committee, the ship's class will be liable to be withdrawn.

### **Section 15**

#### **RECLASSIFICATION OF SHIPS**

**1501** When reclassification is desired for a ship for which the class previously assigned has been withdrawn, the Committee will direct a Special Survey for Reclassification, appropriate to the age of the ship and the circumstances of the case, to be carried out by the Society's Surveyors.

If at such survey the ship be found or placed in a good and efficient condition in accordance with the requirements of the Rules and Regulations, the Committee will be prepared to reinstate her original class or assign such other class as may be deemed necessary.

The date of reclassification will be recorded in the *Supplement* to the *Register Book*.



## Chapter C

# PERIODICAL SURVEY REGULATIONS

### Section 1

#### ANNUAL AND DOCKING SURVEYS

##### ANNUAL SURVEYS

**101** Annual Surveys as required by B 801 should, whenever practicable, be held concurrently with statutory annual or other load line surveys.

**102** The Surveyor is to satisfy himself as to the efficient condition of the following:—

Hatchways on freeboard and superstructure decks, ventilator and air pipe coamings, exposed casings, fiddley openings, skylights, flush deck scuttles, deckhouses and companionways, superstructure bulkheads, side, bow and stern doors, side scuttles and deadlights, ash chutes and other openings, together with all closing appliances.

Means of ensuring watertightness of steel hatch covers.

Scuppers and sanitary discharges (so far as practicable) with valves; guard rails and bulwarks; freeing ports, gangways and lifelines; fittings and appliances for timber deck cargoes.

The Surveyor should satisfy himself regarding the freeboard marks on the ship's side.

Where, on ship-borne barges, Intermediate Surveys are permitted as an alternative to Annual Surveys, all the hatch covers are to be hose tested at every survey.

**103** The Surveyors are to examine the steering arrangements. Attention is to be paid to all parts of rod and chain gears. All pins are to be examined and the chain in the vicinity of the blocks is to be cleaned and examined for wear and tear. Any length of chain so worn that its mean diameter at its most worn part is reduced by 11 per cent or more from its nominal diameter is to be renewed.

All replacements of chains are to be subjected, at a recognized Proving Establishment (*see* D 3420 and Appendix 2 to Chapters P and Q), to the proof tests as set forth for short link cables in P 8 and the certificates are to be produced. It is recommended that, in addition, the breaking test as required in P 8 should be applied to these chains.

It is recommended that repaired chains be tested by the repairers and a certificate to that effect produced.

It is recommended that a set of spares be provided.

The various parts of the auxiliary steering gear are to be assembled and examined in order to ascertain that the gear is in good and workable condition.

**104** The Surveyor is to examine internally a forward and an after hold or tank at the second Annual Survey after the fourth and subsequent Special Surveys on a dry cargo ship and the third and subsequent Special Surveys on a tanker.

REVISED  
SEE NOTICE  
No. 2

## DOCKING SURVEYS

(See B 802)

105 When a ship is in drydock or on a slipway she is to be placed on blocks of sufficient height, and proper staging is to be erected as may be necessary for the examination of the shell plating, sternframe and rudder.

→ Attention is to be given to parts of the structure particularly liable to excessive corrosion or to deterioration from causes such as chafing and lying on the ground and to any undue unfairness of the plating of the bottom.

REVISED  
SEE NOTICE No. 2

## GENERAL

106 At Annual and Docking Surveys the Surveyor should examine the ship so far as is practicable in order to satisfy himself as to her general condition.

107 When chain cables are ranged the anchors and cables should be examined by the Surveyor.

108 The requirements for the survey of main and auxiliary engines, boilers and electrical equipment are set forth in C 6 to C 12.

## ANNUAL AND BIENNIAL SURVEYS OF FIRE EQUIPMENT

109 The arrangements for fire protection, detection and extinction in passenger ships are to be examined annually, and those in cargo ships biennially.

Surveys carried out by the National Authorities of the countries in which the ships are registered may be accepted as meeting these requirements.

## SURVEYS FOR DAMAGE OR ALTERATIONS

110 At any time when a ship is undergoing damage repairs or alterations, any exposed parts of the structure normally difficult of access should be specially examined, e.g. if any part of the main or auxiliary machinery, including boilers, or insulation or fittings is removed for any reason the steel structure in way should be carefully examined by the Surveyor, or when cement in the bottom or covering on decks is removed the plating in way should be examined before the cement or covering is relaid.

Section 2

## SPECIAL SURVEYS—HULL REQUIREMENTS

(For Tankers, see also C 3.)

(A) At the Special Survey of ships under 5 years old.—THE REQUIREMENTS OF AN ANNUAL SURVEY (see 102 and 103) ARE TO BE COMPLIED WITH, IN ADDITION TO THE FOLLOWING:—

201 The ship is to be placed on blocks of sufficient height in a drydock, or on a slipway; proper staging is to be erected as necessary and the shell plating, sternframe and rudder are to be examined.

The rudder is to be lifted for examination of pintles if considered necessary by the Surveyor.

202 The holds, 'tween decks, peaks, deep tanks, engine and boiler spaces, coal bunkers and other spaces are to be cleared and cleaned as necessary and examined. The bilges and limbers all fore and aft are to be cleaned and the structure examined. Platform plates in engine and boiler spaces are to be lifted as may be necessary for the examination of the structure below.

Where necessary close and spar ceiling, lining and pipe casings are to be removed for examination of the structure.



203 In ships having a single bottom, a sufficient amount of close ceiling is to be lifted all fore and aft on each side from the bottom and bilges to permit the structure below to be examined.

204 In ships having a double bottom, a sufficient amount of ceiling is to be removed from the bilges and inner bottom to enable the condition of the plating to be ascertained. If it is found that the plating is clean and in good condition, and free from rust, the removal of the remainder of ceiling may be dispensed with. The Surveyor may waive the removal of heavy reinforced compositions if there is no evidence of leakages, cracking or other faults in the composition.

205 The steelwork is to be exposed and cleaned as may be required for its proper examination by the Surveyor. Careful examination is to be made of parts of the structure particularly liable to excessive corrosion or to deterioration from causes such as chafing, lying on the ground, or handling of cargo.

Attention is to be given to the shell plating in way of side, bow and stern doors, ash chutes and other openings.

The Surveyor may require to ascertain by drilling or other approved means, the thickness of the material in any portion of the structure where signs of wastage are evident or wastage is normally found. Any parts of the structure which are found defective or materially reduced in scantlings are to be made good by materials of the approved scantlings and quality. Attention is to be given to the structure in way of discontinuities. Surfaces are to be recoated as necessary.

206 In cases where the inner surface of the bottom plating is covered with cement, asphalt, or other composition, the removal of this covering may be dispensed with, provided it be inspected, tested by beating or chipping, and found sound and adhering satisfactorily to the steel.

207 Double bottom compartments, peak tanks and all other tanks are to be tested by a head sufficient to give the maximum pressure that can be experienced in service.

Tanks may be tested afloat provided their internal examination is also carried out afloat.

Tanks forming part of the main structure, except as stated below, are to be cleaned and examined internally, special attention being given to tanks under boiler spaces. Tanks (excluding peak tanks) used exclusively for oil fuel or for oil fuel and fresh water ballast need not be examined internally provided, after external examination and testing in accordance with the requirements set out above, the Surveyor finds the condition of these compartments satisfactory.

Double bottom tanks used for oil fuel which require to be filled with sea water ballast after the fuel has been consumed need not all be examined internally provided that, after both the above external examination and testing and an internal examination of the after end of one forward tank, the Surveyor is satisfied with the condition.

On ship-borne barges all tanks and cofferdams are to be air tested.

208 All decks, casings and superstructures are to be examined. Attention is to be given to the corners of openings and other discontinuities in way of strength decks and top sides.

209 Wood decks or sheathing are to be examined; if decay or rot is found or the wood is excessively worn, the wood should be renewed. When a wood deck, laid on stringers and ties, originally required to be 75 mm is worn to 65 mm, or 65 mm to 50 mm, it is to be renewed.

Attention is to be given to the condition of the plating under wood decks, sheathing or other deck covering. If it is found that such coverings are broken or are not adhering closely to the plating, sections should be removed as necessary to ascertain the condition of the plating. *See also C 110.*

210 The masts, standing rigging and anchors are to be examined. If the chain cables are ranged they should be examined. *See Table D 34.2 for renewals.*

The Surveyor should satisfy himself that there are sufficient mooring ropes on board and also that a towline is provided when this is a Rule requirement.

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211 The steering gear, and its connections and control systems (main and alternative) are to be examined. The various parts of the auxiliary steering gear are to be assembled and examined.

212 The windlass (*see* C 602), hand pumps, suction, watertight doors, air and sounding pipes are to be examined. When examining tanks internally the Surveyor should see that striking plates are fitted under sounding pipes.

213 Where holds are insulated for the purpose of carrying refrigerated cargoes, and the hull in way of the insulation was examined by the Society's Surveyors at the time such insulation was fitted, it will be sufficient to remove the limbers and hatches to enable the framing and plating in way to be examined; in other cases additional insulation is to be removed as necessary to satisfy the Surveyor as to the condition of the structure. *See also* N 8.

214 The Surveyor is to satisfy himself as to the efficient condition of the following:—

Means of escape from (a) machinery spaces, (b) crew and passenger spaces, (c) spaces in which crew are normally employed.

Means of communication between (a) bridge and engine room, (b) bridge and alternative steering position.

Helm indicator, protection of aft steering wheel and gear.

215 For surveys of machinery, electrical equipment, boilers, steam pipes and screwshafts, *see* C 6 to C 12.

(B) At each Special Survey of ships between 5 and 10 years old.—THE FULL REQUIREMENTS OF 201 TO 215 ARE TO BE COMPLIED WITH, TOGETHER WITH THE FOLLOWING:—

216 A sufficient amount of ceiling in the holds and in coal bunkers is to be removed from the bilges and inner bottom to enable the condition of structure in the bilges, the inner bottom plating, pillar feet, and the bottom plating of bulkheads and tunnel sides to be examined. If the Surveyor deems it necessary, the whole of the ceiling is to be removed.

217 In ships having a single bottom the limber boards and ceiling equal to not less than three strakes all fore and aft on each side are to be removed, one such strake being taken from the bilges. Where the ceiling is fitted in hatches, the whole of the hatches and at least one strake of ceiling in the bilges are to be removed. If the Surveyor deems it necessary the whole of the ceiling and limber boards are to be removed.

218 Tanks (excluding peak tanks) used exclusively for oil fuel or for oil fuel and fresh water ballast need not all be examined internally provided that, from an external examination and testing and from an internal examination of the after end of one forward double bottom tank, and of one selected deep tank, the Surveyor is satisfied with the condition.

Lubricating oil tanks need not be examined internally.

219 The chain cables are to be ranged for inspection, and the anchors and chains examined. If any length of chain cable is found to be reduced in mean diameter at its most worn part by 11 per cent or more from its nominal diameter, it is to be renewed.

220 The chain locker is to be cleaned and examined internally.

(C) At each Special Survey of ships over 10 years old.—THE FULL REQUIREMENTS OF 201 TO 220 ARE TO BE COMPLIED WITH, TOGETHER WITH THE FOLLOWING:—

221 The steel work is to be cleaned and the rust removed.



222 Casings of air, sounding, steam and other pipes, spar ceiling and lining in way of the side scuttles are to be removed as required by the Surveyor.

223 If the Surveyor is satisfied after removal of portions of the ceiling in the holds, that the steelwork is in good condition, free from rust, and coated, the removal of the whole may be dispensed with. In coal bunkers, however, the whole of the ceiling is to be removed.

224 Attention is to be given by the Surveyor to the inside of coal bunkers and the parts in way of the boilers.

225 Attention is also to be paid to the possibility of local wastage and grooving, e.g. at the shell plating along the heel of framing members.

226 All double bottom and other tanks are to be cleaned as necessary to permit their being examined internally, where this is required.

For ships of 10 and not more than 15 years old, tanks (excluding peak tanks) used exclusively for oil fuel, oil fuel and fresh water ballast, or lubricating oil, need not all be examined internally provided, from an external examination and testing and from internal examination of one double bottom tank forward and one aft and one deep tank, the Surveyor is satisfied with the condition.

For ships of 15 and not more than 20 years old, tanks (excluding peak tanks) used exclusively for oil fuel, oil fuel and fresh water ballast, or lubricating oil, need not all be examined internally provided, from an external examination and testing and from an internal examination of at least one double bottom tank amidships, one forward and one aft and one deep tank, the Surveyor is satisfied with the condition. These tanks should be selected so that as many different tanks as possible are examined internally before the ship is 20 years old. For ships 20 years old or over, all tanks should be examined internally, but in those ships operating on a Continuous Survey basis and fitted with nested deep tanks comprising six or more adjoining tanks, such tanks need not all be examined internally provided that at each year of the survey cycle one selected tank from each nest is found from internal examination to be in good condition.

227 The cement chocks on the ship's sides at bilges and decks are to be examined, and portions removed, so that the condition of the shell plating and adjacent steel work can be ascertained. Portions of wood sheathing, or other covering, on steel decks are to be removed as considered necessary by the Surveyor in order to ascertain the condition of the plating.

228 Where the holds are insulated for the purpose of carrying refrigerated cargoes, the limbers and hatches are to be lifted, and sufficient insulation is to be removed in each of the chambers to enable the Surveyor to satisfy himself of the condition of the framing and plating. *See also N 8.*

229 All mast wedging is to be removed and renewed as necessary.

230 For ships of 15 and not more than 20 years old, in addition to the drilling required by 205 to ascertain local wastage, the shell plating between the light and load waterlines and the strength deck plating outside the line of openings are to be gauged by drilling or other approved means to determine the amount of any general diminution in thickness. The gauging is to be done in at least two places in each strake of plating on each side within the midship half-length.

(D) At the first Special Survey held after the ship is 20\* years old and at every Special Survey thereafter.—THE FULL REQUIREMENTS OF 201 TO 229 ARE TO BE COMPLIED WITH, TOGETHER WITH THE FOLLOWING:—

231 In addition to the drilling required by 205 to ascertain local wastage, the shell plating and plating of strength decks are to be gauged by drilling or other approved means to determine the amount of any general diminution in thickness. The gauging is to be done in at least two places in each strake of plating on each side within the midship half-length. The remainder of the shell plating between the light and load waterlines and the strength deck plating outside the line of openings, all within the midship half-length, are also to be gauged.

\* For tankers, see C 307.



All paint and rust is to be entirely removed before the plates are gauged by the Surveyor and the actual thicknesses are to be reported in detail to the Committee. Where drilled plates are renewed the thickness of adjacent plates in the same strake should be reported.

The thickness of bottom plating in way of cement is to be ascertained unless the Surveyor, after making an internal and external examination, is entirely satisfied that this is unnecessary. Selected portions of the cement are to be removed from the bottom and bilge if required by the Surveyor.

232 Where the holds are insulated for the purpose of carrying refrigerated cargoes, the limbers and hatches are to be lifted, and sufficient additional insulation is to be removed in each of the chambers to enable the Surveyor to satisfy himself of the condition of the steel structure, and to enable the thickness of the shell plating to be ascertained as required by 231.

### Section 3

#### **SPECIAL SURVEYS—TANKERS**

##### **HULL REQUIREMENTS ADDITIONAL TO THOSE STATED IN C 2**

#### **Preparation and Inspection of Tanks**

301 At all Special Surveys all cargo tanks and cofferdams are to be cleaned out, thoroughly cleared of gas, and examined. Every precaution is to be taken to ensure safety during inspection.

Attention is to be given to the inside of the bottom plating in order to ensure that there is no excessive pitting of the plating. When extensive pitting is found care should be taken to preserve the longitudinal strength of the bottom by the requisite renewals or repairs. In cases where cement has been laid in the bottom the Surveyor is to satisfy himself that there is no active corrosion under the cement.

302 The strums of the cargo suction pipes are to be removed to facilitate examination of the shell plating and bulkheads in that vicinity, unless other means for visual inspection of these parts are provided.

303 The attachment to the structure and condition of anodes in tanks is to be examined.

#### **Testing**

304 Each cargo tank bulkhead is to be tested at Special Surveys A and B by filling alternate tanks with water to the top of the hatchway. But at subsequent Special Surveys, or earlier if considered necessary by the Surveyor, all tanks are to be tested.

305 Tanks may be tested when the ship is afloat, provided the internal examination of the bottom is also carried out afloat.

306 Where extensive repairs have been effected to the shell plating, the tanks should be tested to the Surveyor's satisfaction.

#### **Determination of Thickness**

307 The requirements of 231 are to be complied with at every Special Survey after the ship is 10 years old except that, in respect of the deck plating, every deck plate within the midship half-length is to be gauged. All gaugings are to be taken in way of tanks.

### Section 4

#### **LIQUEFIED GAS CARRIERS**

##### **ANNUAL AND SPECIAL SURVEYS—REQUIREMENTS ADDITIONAL TO THOSE STATED IN C 1, C 2 AND C 3**

#### **Preparation before Survey**

401 Prior to inspection of cargo tanks, cofferdams, associated piping, fittings or equipment, the respective items are to be cleaned and thoroughly cleared of gas. Every precaution is to be taken to ensure safety during inspection.



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**402** Where the maximum vapour pressure for which the cargo tanks have been approved as recorded in the *Register Book* is  $0,7 \text{ N/mm}^2$  ( $0,7 \text{ kgf/cm}^2$ ), or less, the inner surfaces of the tanks are to be examined annually.

Where submerged electrically driven pumps are fitted in the cargo tanks, the pumps, motors, control devices and interlocks are to be examined annually as required by 404.

Liquid level indicating devices, high level alarms, monitoring systems for revealing possible gas leakage, and arrangements for inerting the tanks and containment spaces, are to be examined and tested to ascertain that they are in good working order.

**Special Surveys**

**403** At each Special Survey of the ship the tanks are to be examined internally, also externally so far as practicable, particular attention being paid to the plating in way of supports and securing arrangements, mountings and pipe connections, also to sealing arrangements at the deck.

Where the tanks are insulated, portions of the insulation are to be removed if required by the Surveyor to enable him to ascertain the condition of the plating.

Internal fittings are to be examined, all valves and cocks in direct communication with the interiors of the tanks are to be opened out for inspection and any pipes connecting them to the tanks are to be examined internally so far as practicable.

Liquid level indicating devices, high level alarms, monitoring systems for revealing possible gas leakage, and arrangements for inerting the tanks and containment spaces, are to be examined and tested to ascertain that they are in good working order.

Where provision is made for recording the temperature of the ship's structure adjacent to the tanks, the correct functioning of the apparatus, including audible alarms, is to be verified.

Pressure relief valves are to be opened out for inspection and subsequently adjusted to lift at a pressure not more than 3 per cent above the maximum vapour pressure for which the tanks have been approved. The valves may be removed from the tanks for the purpose of making this adjustment which may be effected under pressure of air or other suitable medium.

Vacuum relief valves are to be opened out, examined and tested to establish that they are in good working order.

Where the approved maximum vapour of the cargo tanks is  $0,07 \text{ N/mm}^2$  ( $0,7 \text{ kgf/cm}^2$ ), or less, the tanks are to be tested by a head of water 2,45 m above the top of the tank or 610 mm above the top of the hatch, whichever is the greater. Where access to the outside of the cargo tanks is not possible, other proposals for leak testing of the cargo tanks will be considered.

Where the approved maximum vapour pressure is above  $0,07 \text{ N/mm}^2$  ( $0,7 \text{ kgf/cm}^2$ ), the tanks are to be tested by pressure of water equal to one and a quarter times the approved maximum vapour pressure. Where these tanks are insulated, at the second Special Survey and at each alternate Special Survey thereafter, the insulation is to be removed in way of all supports and connections to the tanks prior to the water pressure test.

Where non-corrosive cargoes only are carried in uninsulated cylindrical tanks fitted in the ship with their longitudinal axes approximately vertical, and the cargoes are not discharged by the admission of water to the tanks, proposals will be considered, upon application by the Owners, to omit the hydraulic test, provided the tanks have been constructed in accordance with the Rules for Welded Pressure Vessels, Class 1, including stress relieving heat treatment, and the Surveyor is satisfied with their internal and external condition. Proposals to limit the amount of opening out of valves, cocks and pressure relief valves at each Special Survey will be considered provided all valves, etc., are seen in rotation in the course of each two consecutive Special Surveys.

Where insulation is attached to the hull structure, special consideration will be given to the necessity of removing it at Special Surveys but, in general, provided the Surveyor is satisfied that it is adhering properly and there are no traces of cold spots, this will not be required until the ship is at least 8 years old. An examination of the wing tanks, double bottom tanks and transverse cofferdams, when the cargo tanks are loaded with liquefied gas at the minimum approved temperature, will be required at the Special Survey or at a convenient date immediately prior thereto.



**404** Where submerged electrically driven pumps are fitted in the cargo tanks, at each Annual and each Special Survey the pumps and motors are to be withdrawn from the tanks and opened out for examination of the condition of the stator winding insulation, evidence of any damage due to thermal expansion and contraction and bearing wear. Any sludge deposits in the motor windings or casings are to be removed and insulation resistances, including those of the motors and supply cables, are to be measured before opening out and after refitting. The portions of supply cables within the cargo tanks and the cable glands are to be examined for signs of deterioration and/or gas leakage.

The control devices and interlocks actuated by pressure or liquid level in the tanks and master key switches, which cut off the supply of current to the motors, are to be checked under simulated working conditions and if necessary re-calibrated.

Where deep well pumps are fitted in the cargo tanks, at each Special Survey the control devices which cut off the supply of current to the motors are to be checked under simulated working conditions and if necessary re-calibrated.

**405** Where refrigeration equipment is installed, either for maintaining the liquid cargo at the carrying temperature or for re-liquefying the "boil-off" and returning it to the tanks, Running and Special Surveys of the equipment are to be carried out in accordance with the requirements of Chapter N, so far as applicable.

In addition, at each Survey the ventilating fans and motors for the refrigerating machinery rooms are to be examined under working conditions and the operation of the temperature indicating equipment and the refrigerating plant checked by examination of the log records.

## **Section 5**

### **DREDGERS, HOPPER DREDGERS, SAND CARRIERS, HOPPER BARGES AND RECLAMATION CRAFT**

**501** The survey requirements of Chapter C are to be complied with, and in addition the requirements listed below are to be complied with as applicable. Where surveys are required to be made on dredging or hopper equipment such as gantries, bottom doors and their operating gear, positioning spuds and suction pipe attachments, these will be limited to the extent considered necessary by the Surveyor to satisfy himself that their condition or malfunction will not adversely affect the ship's structure.

#### **Docking Surveys**

**502** Where applicable the docking survey is to include the examination of hopper doors and their fittings, and of hopper valves.

#### **Special Surveys of ships under 5 years old**

**503** Hoppers are to be cleared and cleaned as necessary and examined.

Where applicable, hopper doors or valves are to be opened and closed as far as is practicable, but keel blocks need not normally be moved specially to permit this to be done.

The integrity of hopper overflows and diluting water inlet and distribution structures is to be confirmed. Weir valves and sluices are to be tested to ensure proper operation, particular attention being paid to the lower weir when weirs are fitted at more than one level.

Attention is to be given to shell plating in way of hopper overflows.

The attachment to the ship's structure of all main items of dredging equipment, including gantries, "A" frames and spud control gear supports, is to be carefully examined to ensure that no fracture is present.

#### **Special Surveys of ships between 5 and 10 years old**

**504** Additional requirements as for ships under 5 years old.



**Special Surveys of ships over 10 years old**

505 Attention is to be given by the Surveyor to the structure in way of dredging pumps.

Hopper doors and valves are to be checked for proper operation and their hinges, control gear and other fittings examined for wear or distortion. All seals and wear-down strips are to be replaced if necessary, but a watertight seal is not normally required. Attention is to be paid to areas likely to be suffering from excessive erosion.

Those items of dredging gear and equipment whose efficiency is not part of classification but whose failure or malfunctioning is, nevertheless, likely adversely to affect the ship's structure, are to be examined to ensure that the structural integrity of the ship is maintained.

**Section 6****GENERAL REQUIREMENTS—MACHINERY****APPLICABLE TO ALL SHIPS****At each Survey held in Drydock**

601 When the ship is in drydock the propeller, sternbush and sea connection fastenings and the gratings at the sea inlets are to be examined. The clearance in the sternbush or the efficiency of the oil gland should be ascertained.

**Complete Surveys**

602 At each Complete Survey required by B 809 the following parts are to be examined:—

**SEA CONNECTIONS**

While the ship is in drydock all openings to the sea in the machinery spaces and pump rooms with the valves, cocks and the fastenings with which these are connected to the hull.

**SHAFTING**

All shafts (except screwshafts and tube shafts for which special arrangements are detailed in C 12), thrust block and all bearings. The lower halves of bearings need not be exposed if alignment and wear are found acceptable.

REDUCTION GEARS, complete with all wheels, pinions, shafts, bearings and gear teeth.

AUXILIARY ENGINES, auxiliary air compressors with their intercoolers, filters and/or oil separators and safety devices, and all pumps and components used for essential services.

**STEERING MACHINERY****WINDLASS**

EVAPORATORS and their safety valves, which should be seen in operation under steam.

**SECURING ARRANGEMENTS**

The holding down bolts and chocks of main and auxiliary engines, gearcases, thrust blocks and tunnel bearings.

**AIR RECEIVERS**

All air receivers for essential services with their mountings, valves and safety devices are to be cleaned internally and examined internally and externally. If internal examination of the air receivers is not practicable, they are to be tested hydraulically to 1.3 times the working pressure.

**PUMPING ARRANGEMENTS**

The valves, cocks and strainers of the bilge system including bilge injection, are to be opened up as considered necessary by the Surveyor and, together with pipes, are to be examined and tested under working conditions. The oil fuel, feed and lubricating oil systems and the ballast connections and blanking arrangements to deep tanks which may carry liquid or dry cargoes, together with all pressure filters, heaters and coolers used for essential services, are to be opened up and examined or tested as considered necessary by the Surveyor. All safety devices for the foregoing items are to be examined.

**FUEL TANKS AND FITTINGS**

Fuel tanks which do not form part of the ship's structure are to be examined and, if considered necessary by the Surveyor, they are to be tested to the pressure specified for new tanks. The tanks need not be examined internally at the first survey if they are found satisfactory on external inspection. All mountings, fittings and deck controls are to be examined so far as practicable.

**SPARE GEAR**

The spare gear is to be checked.

**REMOTE AND/OR AUTOMATIC CONTROLS**

Where remote and/or automatic controls are fitted for essential machinery, they are to be tested to demonstrate that they are in good working order.

In addition to the above, detailed requirements for steam and oil engines, electrical installations and boilers are given in C 7, C 8, C 9 and C 10 respectively. In certain instances, upon application by the Owner or where indicated by the maker's servicing recommendations, the Committee will give consideration to the circumstances where deviation from these detailed requirements is warranted, taking account of design, appropriate indicating equipment (e.g. vibration indicators) and operational records.

**Section 7****STEAM ENGINES—DETAILED REQUIREMENTS****Complete Surveys**

**701** In addition to the requirements of C 6 the working parts of the main engines and attached pumps and of auxiliary machinery used for essential services including bulkhead stop valves, manoeuvring valves, cylinders, pistons, valves and valve gear, piston rods, connecting rods, crossheads and guides, the crankshafts of reciprocating engines and the blading, rotors and casings of turbine machinery are to be opened up and examined.

Condensers, steam reheaters, desuperheaters which are not incorporated in the boilers and any other appliances used for essential services are to be examined to the satisfaction of the Surveyor, and if considered necessary they are to be tested.

The manoeuvring of the engines is to be tested under working conditions.

**702** Exhaust steam turbines supplying power for main propulsion purposes in conjunction with reciprocating engines are, together with their gearing and appliances, steam compressors or electrical machinery, to be examined so far as practicable. Where cone connections to internal gear shafts are fitted, the coned ends are to be examined so far as practicable.

**703** In steam ships having essential auxiliary machinery driven by oil engines, the prime movers of these auxiliaries are to be examined as detailed in C 801.



**Section 8****OIL ENGINES—DETAILED REQUIREMENTS****Complete Surveys**

**801** In addition to the requirements of C 6, the Complete Survey is to consist of the opening out and examination of the following parts: cylinders, covers, valves and valve gear, fuel pumps and fittings, scavenge pumps, scavenge blowers and their prime movers, superchargers, compressors their intercoolers filters and/or oil separators and safety devices, pistons, piston rods, crossheads, guides, connecting rods, crankshafts and all bearings, clutches, reverse gears, attached pumps, cooling system, crankcase door fastenings and explosion relief devices. Selected pipes in the starting air system are to be removed for internal examination and hammer-tested. If an appreciable amount of lubricating oil is found in the pipes, the starting air system is to be thoroughly cleaned internally by steaming or other suitable means. Some of the pipes selected are to be those adjacent to the starting air valves at the cylinders and to the discharges from the air compressors. The electric ignition system, if fitted, is to be examined and tested. The manœuvring of engines is to be tested under working conditions.

Where steam is used for essential purposes, the condensing plant, feed pumps, and oil fuel burning plant, are to be examined and the steam pipes examined and tested as detailed in C 11.

**802** Gas turbines and free piston gas generators: in addition to the requirements of C 6, the Complete Survey is to consist of the opening and examination of the following parts: the blading, rotors and casings of the turbines, the impellers or blading, rotors and casings of the air compressors, the combustion chambers, burners, intercoolers, heat exchangers, gas and air pressure piping and fittings, starting and reversing arrangements.

Where gas turbines operate in conjunction with free piston gas generators, the following parts of the latter are to be opened and examined: the gas and air compressor cylinders and pistons and the compressor end covers, the valves and valve gear, fuel pumps and fittings, synchronizing and control gear, cooling system, explosion relief devices, gas and air piping, receivers and valves including by-pass. The manœuvring of engines is to be tested under working conditions.

**Section 9****ELECTRICAL EQUIPMENT**

**901** At each Complete Survey the electrical equipment is to be examined and tested in accordance with 902 to 911.

**NOTE.** In cases where the Committee has consented to Continuous Surveys, the electrical equipment may also be included in the survey cycle. See B 810.

**902** A test for insulation resistance is to be made on the cables, switchgear, generators, motors, heaters, lighting fittings, etc., and the insulation resistance is to be not less than 100 000 ohms between all insulated circuits and earth. The installation may be subdivided to any desired extent by opening switches, removing fuses or disconnecting appliances for the purpose of this test.

**903** The fittings on main and emergency switchboards, section boards and sub-distribution fuse boards are to be examined and over-current protective devices and fuses inspected to verify that they provide suitable protection for their respective circuits.

**904** Generator circuit-breakers are to be tested, so far as practicable, to verify that the protective devices including preference tripping relays, if fitted, operate satisfactorily.

**905** The electric cables are to be examined so far as practicable without undue disturbance of fixtures or casings unless opening up is considered necessary as a result either of observation or of the tests required by 902.

**906** The generator prime movers are to be surveyed as required by C 7 and C 8 and the governing of the engines tested. The motors concerned with essential services together with associated control and switch gear are to be examined and, if considered necessary, are to be operated so far as practicable under working conditions. All generators and steering gear motors are to be examined and are to be operated under working conditions, though not necessarily under full load or simultaneously.



907 Where transformers or electrical apparatus associated with supplies to essential services are oil-immersed, the Owners are to arrange for samples of oil to be taken and tested for breakdown voltage, acidity and moisture by a competent testing authority and a certificate giving the test results is to be furnished to the Surveyor.

908 Where electro-magnetic couplings are fitted, the air gaps to be measured and reported, and any excessive eccentricity corrected. The couplings and associated switchgear are to be examined and tested.

909 Navigation light indicators are to be tried under working conditions and correct operation on the failure of supply and failure of navigation lights verified.

910 In passenger ships the emergency source of power and its associated circuits and, where fitted, the temporary source of power and its automatic arrangements are to be tested. *See M 111.*

In cargo ships the emergency source of power and its associated circuits are to be tested. *See M 111.*

#### Electric Propelling Machinery

911 Where the ship is electrically propelled, the propulsion motors, generators, cables, and all ancillary electrical gear, exciters and ventilating plant (including coolers) associated therewith are to be examined and the insulation resistance to earth is to be tested. Special attention is to be given to windings, commutators and slip-rings. The operation of protective gear and alarm devices is to be checked so far as practicable. Insulating oil, if used, is to be tested in accordance with 907. Interlocks intended to prevent unsafe operations or unauthorized access are to be checked to verify that they are functioning correctly. Emergency overspeed governors are to be tested.

### Section 10

#### BOILER SURVEYS

1001 Water tube boilers supplying steam to the main propelling machinery (other than cylindrical boilers having corrugated or plain furnaces in conjunction with water tubes) and steam heated steam generators are to be surveyed at 2-yearly intervals.

All other boilers (including domestic boilers having a working pressure exceeding  $0,34 \text{ N/mm}^2$  ( $3,5 \text{ kgf/cm}^2$ ) and a heating surface exceeding  $4,65 \text{ m}^2$ ), also press boilers and similar apparatus in floating whale oil factories, and exhaust gas steam generators and economizers, are to be surveyed at 2-yearly intervals until they are 8 years old and subsequently annually. Upon application by the Owners and subject to satisfactory survey reports being received, the Committee will be prepared to consider, in the case of suitable auxiliary boilers of the water tube type, continuing the 2-yearly survey after the boilers are 8 years old.

In fired boilers employing forced circulation the pumps used for this service are to be opened and examined at each boiler survey.

1002 At the surveys described in 1001 the boilers, superheaters, economizers and air heaters are to be examined internally and externally, and where considered necessary the pressure parts are to be tested by hydraulic pressure and thickness of plates and tubes and size of stays are to be ascertained to determine a safe working pressure. The principal mountings on boilers, superheaters and economizers are to be opened up and examined and the safety valves adjusted under steam to a pressure not greater than 3 per cent above the approved working pressures of the respective parts. The remaining mountings are to be examined externally and are to be opened up for internal examination if considered necessary by the Surveyor. Collision chocks, rolling stays and boiler stools are to be examined and maintained in efficient condition.

1003 The oil fuel burning system is to be examined under working conditions and a general examination made of fuel tank valves, pipes, deck control gear and oil discharge pipes between pumps and burners.

1004 At each survey of a cylindrical boiler which is fitted with smoke tube superheaters, the saturated steam pipes are to be examined as detailed in C 1104.



**Section 11****STEAM PIPES****Steel Pipes**

**1101 INCIDENCE OF SURVEYS.**—Saturated steam pipes, also superheated steam pipes where the temperature of the steam at the superheater outlet is not over 454°C, are to be surveyed 8 years from the date of build (or installation) and thereafter at 4-yearly intervals. Superheated steam pipes where the temperature of the steam at the superheater outlet is over 454°C are to be surveyed 4 years from the date of build (or installation) and thereafter at 4-yearly intervals.

**SCOPE OF SURVEYS**

**1102 PIPES HAVING BOLTED JOINTS.**—At each survey a selected number of main steam pipes, also of auxiliary steam pipes over 76,1 mm external diameter supplying steam for essential services at sea, are to be removed for internal examination and hydraulically tested to 1,5 times the working pressure. If these selected pipes are found satisfactory in all respects, the remainder need not be tested. The pipes are, so far as practicable, to be selected for examination and hydraulic test in rotation so that in the course of surveys all sections of the pipe line will be tested.

**1103 PIPES HAVING WELDED JOINTS.**—Where main and/or auxiliary steam pipes of the category described in 1102 have welded joints between lengths of pipe and/or between pipes and valves, the lagging in way of the welds is to be removed, the welds examined and, if considered necessary by the Surveyor, crack detected. Pipe ranges having welded joints are to be hydraulically tested to 1,5 times the working pressure. Where lengths having ordinary bolted joints are fitted in such pipe ranges and can be readily disconnected, they are to be removed for internal examination and hydraulically tested to 1,5 times the working pressure.

**1104 CYLINDRICAL BOILERS HAVING SMOKE TUBE SUPERHEATERS.**—Where the saturated steam pipes adjoining the saturated steam headers are situated partly in the boiler smoke boxes, all such pipes adjoining and cross-connecting these headers in the smoke boxes are, at the surveys required by 1101, to be included in the pipes selected for examination and testing as defined in 1102. Where the saturated steam pipes inside the smoke boxes consist of steel castings of substantial construction, these requirements need only be applied to a sample casting. Where steel castings are not fitted, the Surveyor is to satisfy himself of the condition of the ends of the saturated steam pipes in the smoke boxes *at each boiler survey* and, if he considers it necessary, a sample pipe is to be removed for examination.

**1105** As an alternative to the requirements of 1102, and provided the saturated steam pipes in smoke boxes are dealt with as detailed in the first paragraph of 1104, the remainder of the pipes may, if the Owner wishes, be hydraulically tested in place to 1,5 times the working pressure. Lagging is to be removed as required by the Surveyor to permit effective examination.

**Copper Pipes**

**1106** At 8 years from the date of build (or installation) and thereafter at 4-yearly intervals all copper steam pipes over 76,1 mm external diameter supplying steam for essential services at sea are to be hydraulically tested to twice the working pressure. At these surveys any of the pipes which may be subject to bending and/or vibration, such as those having expansion or other bends, and closing lengths adjacent to steam driven machinery, are to be annealed before being tested.

**1107** Where it is inconvenient for the Owners to fulfil all the requirements of a steam pipe survey at its due date, the Committee will be prepared to consider postponement of survey, either wholly or in part.

**Section 12****SCREWSHAFTS AND TUBE SHAFTS**

**1201** Screwshafts and tube shafts are to be drawn periodically for examination by the Society's Surveyors.

Where shafts are fitted with continuous liners or approved oil glands, or are made of approved corrosion-resisting material, they normally become due for survey at intervals of 3 years for single screw ships and 4 years for ships having two or more screws. All other shafts should be drawn at intervals of 2 years.



**1202** On the application of Owners, surveys of shafts of single screw ships having continuous liners or approved oil glands, or made of approved corrosion-resisting material may be held at intervals of 4 years, provided the keyway is of the sled-runner or round-ended type having adequate root radius, any sharp edge around the keyway at the surface of the shaft is removed by filing or other suitable means and, at each survey, the shaft is examined by an efficient crack detection method over a length from the after end of the liner (or after end of the sterntube for shafts not fitted with continuous liners) to a position at about one-third of the length of the cone from the large end. Upon application by the Owners and provided the keyway is as described above, a 4-year period will also be allowed before the first survey of the shaft of a new single screw ship and may be allowed for a new or previously unused spare shaft fitted to an existing ship. At the first and subsequent periodical surveys the forward portion of the shaft cone is to be examined by an efficient crack detection method.

**1203** The Committee will be prepared to give consideration to the circumstances of any special case upon application by the Owner.

### Section 13

#### CLASSIFICATION OF SHIPS NOT BUILT UNDER SURVEY

**1301** When classification is desired for a ship not built under the supervision of the Society's Surveyors, application should be made to the Committee in writing.

##### **Hull and Equipment**

**1302** Plans showing the main scantlings and arrangements of the actual ship and any proposed alterations are to be submitted for approval. These should comprise midship section, longitudinal section and decks, and such other plans as may be requested. If plans cannot be obtained or prepared by Owners, facilities are to be given for the Society's Surveyor to take the necessary information from the ship.

Particulars of the process of manufacture and testing of the material of construction should be furnished.

**1303** In all cases the full requirements of C 201 to C 230 are to be carried out. In the case of tankers the requirements of C 301 to C 306 are also to be carried out. Tankers over 10 years old are in addition to comply with C 307, and other ships over 20 years old with C 231 and C 232. During the survey the Surveyors are to satisfy themselves regarding the workmanship and verify the approved scantlings and arrangements. For this purpose, and in order to ascertain the amount of any deterioration, parts of the structure will require to be drilled as necessary. Full particulars of the anchors, chain cables and equipment are to be submitted. Fire protection, detection and extinction are to be in accordance with the Rules (*see* Chapter F). Ships of recent construction will receive special consideration.

**1304** When the full survey requirements indicated above cannot be completed at one time, the Committee may consider granting an interim record for a limited period. The conditions regarding the completion of the survey will depend on the merits of each particular case, which should be submitted for consideration.

##### **Machinery**

**1305** To facilitate the survey, plans of the following items, together with the particulars of the materials used in the construction of the boilers, air receivers and important forgings should be furnished:—

- General pumping arrangements, including air and sounding pipes. (Shipbuilder's plan)
- Pumping arrangements at the forward and after ends of oil tankers and drainage of cofferdams and pump rooms.
- General arrangement of cargo piping in tanks and on deck of oil tankers.
- Piping arrangements for cargo oil (F.P. 60°C or above, closed cup test).
- Bilge, ballast and oil fuel pumping arrangements in the machinery space, including the capacities of the pumps on bilge service.
- Arrangement and dimensions of main steam pipes.
- Arrangement of oil fuel pipes and fittings at settling and service tanks.



Arrangement of oil fuel piping in connection with oil burning installations.  
Oil fuel and cargo oil overflow systems, where these are fitted.  
Arrangement of boiler feed systems.  
Oil fuel settling, service and other oil fuel tanks not forming part of the ship's structure.  
Plans of piping are to be diagrammatic.  
Boilers, superheaters and economizers.  
Air receivers.  
Crank, thrust, intermediate and screw shafting.  
Clutch and reversing gear with methods of control.  
Reduction gearing.  
Propeller (including spare propeller if supplied).  
Electrical circuits.

NOTE. Plans additional to the above should not be submitted unless the machinery is of a novel or special character affecting classification.

Where remote and/or automatic controls are fitted to propulsion machinery and essential auxiliaries, a description of the scheme is to be submitted. Particulars are to be given of the spare gear carried for machinery and control gear and whether maintenance is by repair or replacement.

#### TORSIONAL VIBRATION CHARACTERISTICS

For new ships and ships which have been in service less than 8 years, calculations of the torsional vibration characteristics of the propelling machinery are to be submitted for consideration as required for ships constructed under Special Survey. For older ships the circumstances will be specially considered in relation to their service record and type of machinery installed.

Where calculations are not submitted the Committee may require that the machinery certificate be endorsed to this effect.

When desired by the Owners the calculations and investigation of torsional vibration characteristics of machinery may be carried out by the Society upon special request.

**1306** The main and auxiliary machinery, also feed pipes, compressed air pipes and boilers are to be examined as required at Complete Surveys, and their working pressures are to be determined from their actual scantlings in accordance with the Rules.

The screwshaft is to be drawn and examined.

The steam pipes are to be examined and tested as required by C 11.

The bilge, ballast and oil fuel pumping arrangements are to be examined and amended as necessary to comply with the Rules.

Oil burning installations are to be examined as required at Complete Surveys and found, or amended, to comply with the requirements of the Rules; they are also to be tested under working conditions.

The electrical equipment is to be examined as required at Complete Surveys.

The spare gear is to be in accordance with the Rules.

The whole of the machinery, including essential controls, is to be tried under working conditions to the Surveyor's satisfaction.

First entry reports are to be prepared by the Surveyors.

**1307** Where classification with the Society is desired for a ship which is classed by another recognized Society, special consideration will be given to the scope of the machinery survey.

#### Periodical Surveys

**1308** Periodical surveys are subsequently to be held as in the case of ships built under survey.

# **NOTE**

Chapter D of these Rules is applicable only to ships of 90 m and over in length.

For ships under 90 m in length, see the Rules for the Hull Construction of Steel Ships Under 90 m in Length.



## Chapter D

### HULL CONSTRUCTION

#### Section 1

#### GENERAL

##### Application

**101** This Chapter applies to sea-going ships of normal form and proportions of 90 m and over in length.

Ships of unusual form or proportions, intended for the carriage of special cargoes, or for special or restricted service, will receive individual consideration on the basis of the general standards of these Rules. (For the carriage of liquefied gases, see the *Rules for Ships for Liquefied Gases*.)

**102** The scantlings and arrangements in passenger ships will be specially considered in relation to the general design features.

##### Equivalents

**103** Alternative arrangements or fittings which are considered to be equivalent to the Rules will also be accepted.

##### Definitions

**104** Length,  $L$ , is the distance, in metres, on the summer load waterline from the fore side of the stem to the after side of rudder post, or to the centre of the rudder stock

if there is no rudder post.  $L$  is not to be less than 96 per cent, and need not be greater than 97 per cent, of the extreme length on the summer load waterline.

Amidships is to be taken as the middle of the length,  $L$ , measuring from the fore side of the stem.

In ships with unusual stern arrangement the length,  $L$ , will be specially considered.

**105** Breadth,  $B$ , is the greatest moulded breadth, in metres.

**106** Depth,  $D$ , is measured, in metres, at the middle of the length,  $L$ , from top of keel to top of the deck beam at side on the uppermost continuous deck, or as defined in appropriate Sections.

When a rounded gunwale is arranged, the depth,  $D$ , is to be measured to the continuation of the moulded deck line.

**107** Draught,  $d$ , is the summer draught, in metres, measured from top of keel.

**108** Passenger ship is a ship, engaged on international voyages, which carries more than twelve passengers.

**109** Other parameters are defined in the appropriate Sections.

**Plans to be Submitted**

110 Plans covering the following items are to be submitted:—

Midship section.  
 Longitudinal strength calculations.  
 Longitudinal section.  
 Shell plating (indicating extent of flat of bottom forward).  
 Decks.  
 Watertight bulkheads.  
 Pillars and girders.  
 Deep tanks.  
 Oil fuel bunkers.  
 Arrangement of fore body.  
 Rudder.  
 Sternframe.  
 Propeller brackets.  
 Main engine and thrust seating.  
 Arrangement of after end.  
 Superstructure and deckhouse.  
 Hatchways.  
 Strengthening for navigation in ice.  
 Masts and derrick posts.  
 Scheme of welding.  
 Particulars for calculation of freeboard.  
 Loading Manual.  
 Fire protection, detection and extinction arrangements.

111 See also D 4012 and D 8008 for additional requirements.

**Direct Calculations**

112 The scantlings of structural items may be determined using direct calculations. In such cases, the assumptions made and the calculations are to be submitted for approval.

**Ballasting**

113 Attention should be given to the amount and distribution of water ballast. It has been found that satisfactory service has been obtained when the draught forward is not less than 0,027L and the longitudinal radius of gyration of the ballasted ship is less than 0,25L.

**Cyclic Loading**

114 Where higher tensile steel is used, special attention is to be paid to cyclic loading.

**Materials**

115 Mild steel is to comply with P 2 and higher tensile steel with P 3.

116 The scantlings of those items for which higher tensile steel is used may be reduced as permitted by other Sections of this Chapter.

For this purpose, a higher tensile steel factor  $k$  is to be derived as follows:—

$$k = \frac{245}{Y} \quad \left( k = \frac{25}{Y} \text{ metric} \right)$$

or  $k = 0,725$  ( $k = 0,725$ )  
 whichever is the greater,

where  $Y$  = specified minimum yield stress, or 0,5 per cent proof stress, in  $\text{N/mm}^2$  ( $\text{kgf/mm}^2$ ).

Special consideration will be given to steels where  $Y$  is greater than  $355 \text{ N/mm}^2$  ( $36 \text{ kgf/mm}^2$ ).

For mild steel,  $k$  may be taken equal to 1,0.

117 Where higher tensile steel is used extensively in the main hull structure, a suitable descriptive notation will be inserted in the *Register Book*.

118 Aluminium alloy used for superstructures, deck-houses, hatch covers or other structural members is to comply with P 12.

**Grades of Steel**

119 Steel of a Grade other than A is to be incorporated as required by other Sections of this Chapter.

120 Where higher tensile steel replaces Grades A, B and D mild steel for parts of the structures, then for plates, Grade AH may be used up to and including a thickness of 25,5 mm, and Grade DH is to be used when the thickness of the higher tensile plates exceeds 25,5 mm.

For slab type longitudinals, flame cut from plate, Grade AH may be used up to and including a thickness of 35,5 mm, provided that the carbon equivalent of the steel does not exceed 0,41 per cent, and Grade DH is to be used where the carbon equivalent is greater than 0,41 per cent if the thickness exceeds 20,5 mm.

Grade EH plates are normally to be substituted for Grade E (*but see also D 414*).

For formula for carbon equivalent, see D 3219.

**Plans for Location of Material**

121 To facilitate the ordering of material for repairs, a plan is to be carried in the ship indicating the position and



grades (other than Grade A) of hull structural steel, and any recommendations for welding, working and treatment of such steels.

A plan is also to be placed on board indicating the location and extent of higher tensile steel, together with details of the specification, including mechanical properties, of the steel.

Similar information is to be provided for aluminium alloy or other materials used in the hull construction.

### Method of Construction

122 The Rules apply to all welded construction.

123 Provision is made for longitudinal or transverse framing of shell, decks and bottom, subject to certain limitations given in appropriate Sections of this Chapter.

Where higher tensile steel is used, the requirements of this Chapter are applicable to ships where the bottom and decks are framed longitudinally. Proposals for ships with transverse framing of bottom or deck will be specially considered.

### Distribution of Continuous Longitudinal Material

124 The midship scantlings are to extend over 0,4L amidships and may be reduced gradually to those permitted at the ends except as otherwise required by these Rules.

The hull section modulus requirements for ships of length between 120 and 170 m, and service speed greater than 17,5 knots, in association with a bow shape factor ( $\psi$ ) of more than 0,15, will be specially considered.

The bow shape factor is defined as:—

$$\psi = \frac{100 \sum A_b}{L^{1,5} \times B}$$

$$\text{where } \sum A_b = \frac{b \times a_0}{2} + 0,1L(a_1 + a_2) \text{ m}^2,$$

and  $L$  = length of ship, in metres,

$B$  = breadth of ship, in metres,

$b$  = projection of upper deck at waterline (F.P. to bow line), in metres,

$a_0$  = projection of upper deck at waterline (F.P.), in metres,

$a_1$  = projection of upper deck at waterline (0,1L from F.P.), in metres,

$a_2$  = projection of upper deck at waterline (0,2L from F.P.), in metres.

See also Fig. D 1.1

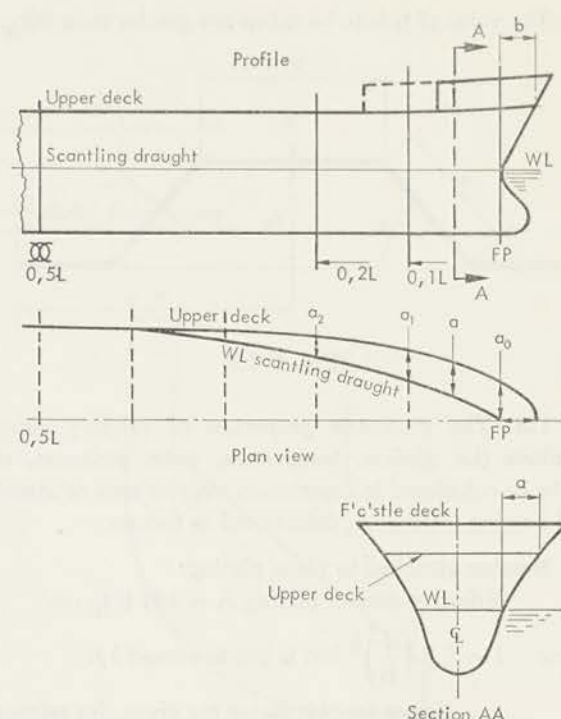


FIG. D 1.1 DERIVATION OF BOW SHAPE FACTOR

### Geometric Properties of Sections

125 The effective geometric properties of rolled or built sections may be calculated directly from the dimensions of the section and associated effective area of attached plating. Alternatively, the curves in the Society's publication *Geometric Properties of Rolled Sections and Built Girders* may be used.

126 The geometric properties of rolled or built stiffener sections and of swedges are to be calculated in association with an effective area of attached load bearing plating of thickness  $t_p$  mm and of width 600 mm or  $40t_p$  mm whichever is the greater. In no case, however, is the width of plating to be taken greater than either the spacing of the stiffeners or the width of flat plating between swedges, whichever is appropriate.

The thickness,  $t_p$ , is the actual thickness of the attached plating. Where this varies, the mean thickness over the appropriate span is to be used.

127 The effective section modulus of a corrugation over spacing  $p$  is to be calculated from the dimensions and, for symmetrical corrugations, may be taken as:—

$$\frac{I}{y} = \frac{d_w}{6000} (3bt_p + ct_w) \text{ cm}^3$$

where  $d_w$ ,  $b$ ,  $t_p$ ,  $c$ ,  $t_w$ , are all in millimetres and are illustrated in Fig. D 1.2, and  $\theta$  is not less than  $40^\circ$ .

The value of  $b$  is to be taken not greater than  $50t_p$ .

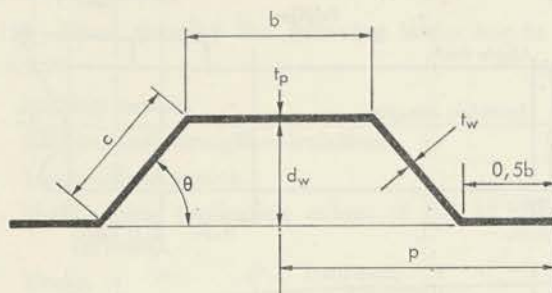


FIG. D 1.2

128 The geometric properties of primary support members (i.e. girders, transverses, webs, stringers, etc.) are to be calculated in association with an area of attached load bearing plating,  $A$ , determined as follows:—

(a) Member attached to plane plating:

$$\text{Effective area of plating } A = 10 f b t_p \text{ cm}^2$$

where  $f = 0,3 \left( \frac{l}{b} \right)^{\frac{2}{3}}$  but is not to exceed 1,0

Values for this factor are given, for reference, in Table D 1.1.

$l$  = the overall length, in metres, of the primary support member,

$b$  = the actual width, in metres, of the load bearing plating. That is, one-half of the sum of spacings between parallel adjacent members or equivalent supports.

$t_p$  = the thickness, in millimetres, of the attached plating. Where this varies, the mean thickness over the appropriate span is to be used.

TABLE D 1.1

$\frac{l}{b}$	$f$	$\frac{l}{b}$	$f$
0,5	0,19	3,5	0,69
1	0,30	4	0,76
1,5	0,39	4,5	0,82
2	0,48	5	0,88
2,5	0,55	5,5	0,94
3	0,62	6 and above	1,00

Intermediate values to be obtained by linear interpolation.

(b) Member attached to corrugated plating:

(i) For members parallel to the direction of corrugations, the effective area is to be taken as that of the face plate of the corrugation.

(ii) For members at right angles to the direction of corrugations, the effective area is to be taken as the area of the face plate of the member.

129 The effective section modulus of a built section may be taken as:—

$$\frac{I}{y} = \frac{a d_w}{10} + \frac{t_w d_w^2}{6000} \left( 1 + \frac{200 (A - a)}{200 A + t_w d_w} \right) \text{ cm}^3$$

where  $a$  = the area, in  $\text{cm}^2$ , of the face plate of the member,

$A$  = the area, in  $\text{cm}^2$ , of the attached plating, see 128,

$d_w$  = the depth, in millimetres, of the section between the inside of the face plate and the attached plating.

Where the member is at right angles to a line of corrugations, the minimum depth is to be taken.

$t_w$  = the thickness, in millimetres, of the web of the section.

#### Determination of Span Point

130 The Rule span,  $S$ , of a stiffening member is generally less than the overall length,  $l$ , by an amount which depends on the design of the end connections.

The span points, between which the value of  $S$  is measured, are to be determined as follows:—

(a) Rolled or built stiffener sections, swedges and corrugations.

The span point is to be taken at the point where the depth of the end bracket, measured from the face of the stiffener, is equal to the depth of the stiffener. Where there is no end bracket, the span point is to be taken at the end of the stiffener.

(b) Primary support members.

The span point is to be taken at a point distant  $b_e$  from the end of the member,

$$\text{where } b_e = b_b \left( 1 - \frac{d_w}{d_b} \right)$$

See also Fig. D 1.3.

131 The Rules assume that the ends of stiffening members are substantially fixed against rotation and displacement. If the arrangement of supporting structure is such that this condition is not achieved, consideration will be given to the effective span to be used for the stiffener.



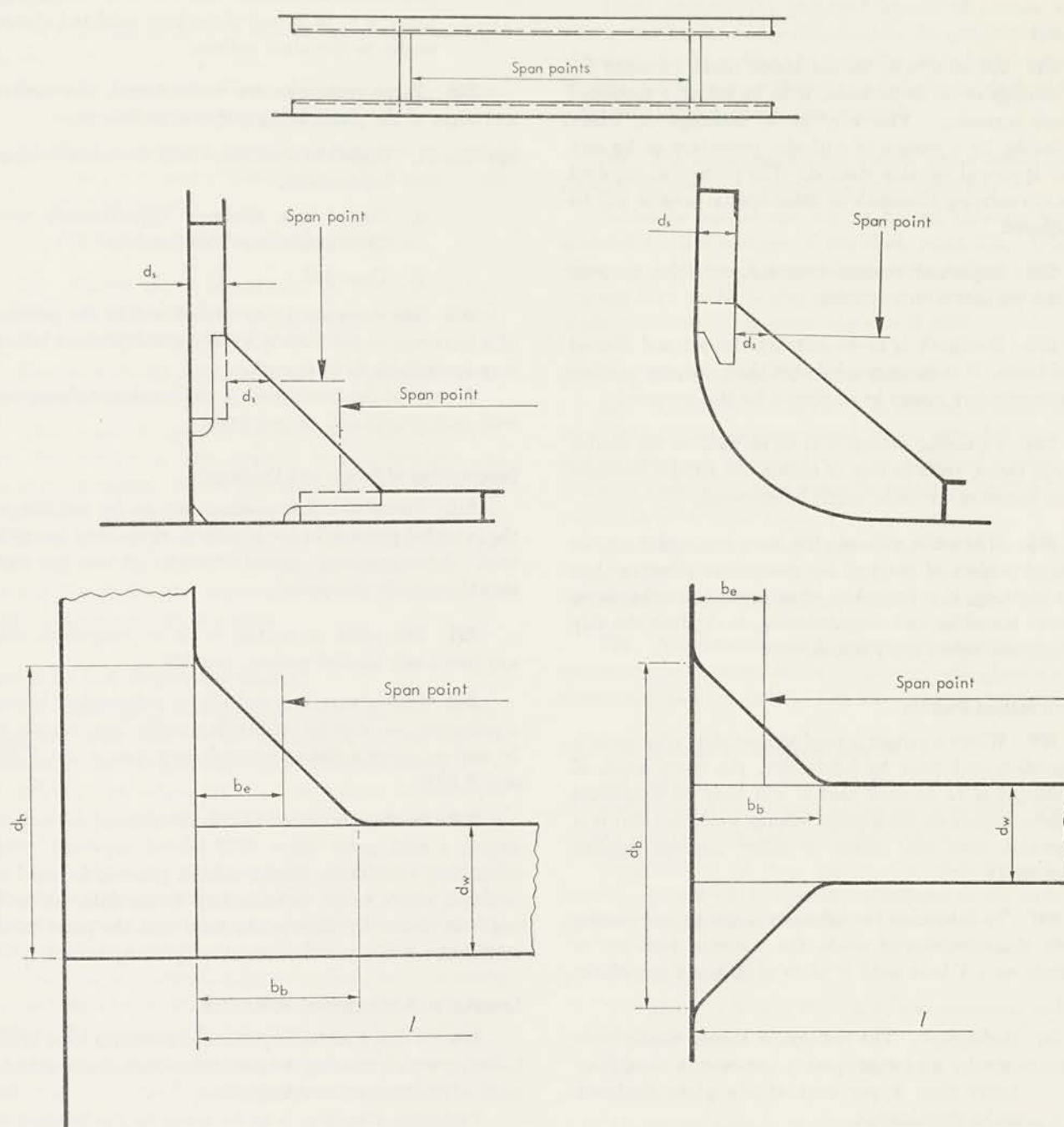


FIG. D 1.3 SPAN POINTS

**Section 2****PROTECTION OF STEELWORK****General**

**201** All steelwork, except inside tanks intended for the carriage of oil or bitumen, is to be suitably protected against corrosion. This may be by coatings or, where applicable, by a system of cathodic protection or by any other approved suitable method. The protection required in tanks carrying chemicals or other special cargoes will be considered.

**202** Impressed current cathodic protection systems are not permitted in any tank.

**203** Steelwork is to be suitably cleaned and cleared of millscale. It is recommended that blast cleaning or other equally effective means be employed for this purpose.

**204** Particular attention is to be paid to the double bottom tanks, areas in way of boilers and similar locations where excessive corrosion might be expected.

**205** Where the millscale has been removed from the external surface of the hull by means less effective than blast cleaning, it is desirable, when several months elapse between launching and commissioning, to drydock the ship immediately before entry into service.

**Prefabrication Primers**

**206** Where a primer is used to coat steel after surface preparation and prior to fabrication, the composition of the coating is to be such that it will have no significant deleterious effect on subsequent welding work and that it is compatible with the paints or other coatings applied subsequently.

**207** To determine the influence of the primer coating on the characteristics of welds, the following tests are to be made on a V-butt weld in plate of 20 to 25 mm thickness:—

- (a) Radiograph. The radiograph should clearly indicate by an image quality indicator a sensitivity better than 2 per cent of the plate thickness under examination.
- (b) Photo-macrograph. This may be of actual size and is to be taken from near each end and from the centre of the butt in the test plate.
- (c) Face and reverse bend test. The test piece is to be bent by pressure or hammer blows round a former of diameter equal to three times the plate thickness.

(d) Impact test. This test is to be carried out at ambient temperature, and specimens are to be prepared in accordance with P 105(d). The Charpy notch is to be in way of the butt weld and at right angles to the plate surface.

**208** Three specimens are to be tested, the surfaces and edges of the plates being prepared as follows:—

- Specimen 1. Coated in accordance with the manufacturers' instructions.
2. Coated to a thickness approximately twice the manufacturer's instructions.
  3. Uncoated.

**209** The tests are to be carried out in the presence of a Surveyor to the Society or by an independent laboratory specializing in such work.

A copy of the test report is to be submitted together with radiographs and macrographs.

**Composition of Paints and Coatings**

**210** Paints or other coatings are to be suitable for the intended purpose in the locations where they are to be used. Unless previously agreed otherwise, at least two coats should generally be applied.

**211** The paint or coating is to be compatible with any previously applied primer. *See* 206.

**212** Paints, varnishes and similar preparations having a nitrocellulose or other highly flammable base are not to be used in accommodation or machinery spaces. *See* F 822 and F 1005.

**213** In ships intended for the carriage of oil cargoes having a flash point below 60°C (closed cup test), paint containing aluminium should not, in general, be used in positions where cargo vapours may accumulate, unless it has been shown by appropriate tests that the paint to be used does not increase the incensive sparking hazard.

**Location and Attachment of Anodes**

**214** Where a cathodic protection system is to be fitted in tanks, a plan showing details of the location and attachment of anodes is to be submitted.

Particular attention is to be given to the location of anodes in relation to the structural arrangements and openings of the tank.

**215** Anodes are to be of approved design and sufficiently rigid to avoid resonance in the anode support. Steel cores are to be fitted and these are to be so designed as to retain the anode even when the latter is wasted.



**216** Anodes are to be attached to the structure in such a way that they remain secure both initially and during service.

The following methods of attachment would be acceptable:—

- (a) Steel core connected to the structure by continuous welding of adequate section.
- (b) Steel core bolted to separate supports, provided that a minimum of two bolts with lock nuts is used at each support.
- (c) Approved means of mechanical clamping.

**217** Anodes are to be attached to stiffeners or may be aligned in way of stiffeners on plane bulkhead plating, but they are not to be attached to the shell.

The two ends are not to be attached to separate members which are capable of relative movement.

Where cores or supports are welded to the main structure, they are to be kept clear of toes of brackets and similar stress raisers. Where they are welded to asymmetrical stiffeners, they are to be connected to the web and the welding is to be kept at least 25 mm away from the edge of the web. In the case of stiffeners or girders with symmetrical face plates, the connection may be to the web or at the centreline of the face plate.

#### Aluminium and Magnesium Anodes

**218** Aluminium and aluminium alloy anodes are permitted in tanks used for the carriage of oil but only in locations where the potential energy does not exceed 275 J (28 kgf m). The weight of the anode is to be taken as the weight at the time of fitting, including any inserts and fitting devices.

The height of the anode is, in general, to be measured from the bottom of the tank to the centre of the anode. Where the anode is located on, or closely above, a horizontal surface (such as a bulkhead girder) not less than 1 m wide provided with an upstanding flange or face plate projecting not less than 75 mm above the horizontal surface, then the height of the anode may be measured above that surface.

Aluminium anodes are not to be located under tank hatches or Butterworth openings unless protected by adjacent structure.

**219** Magnesium or magnesium alloy anodes are permitted only in tanks intended solely for water ballast.

#### External Hull Protection—Impressed Current Systems

**220** When the external hull is protected by means of an impressed current system in association with a suitable

high duty coating, the ship may be eligible for increased interval between drydockings. *See* B 802.

Plans showing the proposed layout of anodes and reference cells, the wiring diagram and the proposed means of bonding in the rudder and propeller are to be submitted. Where the deferment of drydocking is desired, details of the proposed hull coating are also required.

**221** The arrangements for glands where cables pass through the shell are to include a small cofferdam.

Cables to anodes are not to be led through tanks intended for the carriage of low flash point oils. Where cables are led through cofferdams or clean ballast tanks of tankers, they are to be enclosed in a substantial steel tube of about 10 mm in thickness. *See also* M 1623.

#### Scantling Allowance for Corrosion Control

**222** Scantlings in tanks may be reduced in accordance with Table D 2.1 and associated Notes, provided that all surface areas are protected with an approved system of corrosion control. In such cases the notation "(cc)" will be entered in the *Register Book*.

Scantlings in dry compartments may be reduced similarly, but in such cases, only an approved coating system of corrosion control, or equivalent, would be acceptable.

**223** Full particulars of the proposed corrosion control system are to be submitted, and the steelwork plans are to show both the Rule and the corrosion control scantlings.

#### Approved Systems of Corrosion Control

**224** Systems of corrosion control installed in association with reduced scantlings and the notation "(cc)" are to comply with (a) or (b) below, as appropriate.

Combinations of these systems or other systems of corrosion control will be specially considered on the basis of providing equivalent protection.

##### (a) Coating Systems

The proposed coating must have been approved by the Society.

The coating is to be compatible with any previously applied primer. *See* 206.

All surface areas in tanks where scantling allowances have been permitted are to be coated.

The painting specification for these areas is to be submitted and is to include the following information:—

- (i) Details of the surface preparation.
- (ii) Name and type of primer coating (if any).



TABLE D 2.1

ITEM	PERMISSIBLE REDUCTION IN THICKNESS
Keel, Bottom and Side Shell, Deck Plating Bottom and Deck longitudinals Bottom and Deck girders Bulkhead plating protected on one side only	5 per cent
Structural items of tank minimum thickness within oil cargo tanks	1 mm
Side longitudinals, bulkhead stiffeners (where within a protected tank), and all other structural items wholly within the tank, or forming the boundary between two protected tanks, except as listed above	10 per cent

## NOTES

1. The hull midship section modulus and the scantling requirements for longitudinal strength are to be determined before reductions for corrosion control are applied.
2. Where the inner bottom and lower strakes of bulkheads and hopper side plating are liable to grab or bulldozer damage, the reduction is limited to 5 per cent even though both sides are protected.
3. Reductions to shell plating are not affected by the fitting of external protection.
4. Reductions of scantlings of longitudinal items contributing to the hull girder strength will be permitted only if the items are protected throughout the full range of the cargo spaces.

(iii) Name and type of proposed corrosion control coating.

(iv) Method of application, number of coats and total dry film thickness.

(b) **Cathodic Protection Systems**

All surface areas in the tanks above the normal liquid level, with a minimum of all surfaces in the top 1,5 m, are to be coated in accordance with (a) above. The coatings, and any previously applied primers, are to be suitable for use in association with a cathodic protection system. Anodes are to be fitted in the remainder of the tank. The location and attachment of anodes is to comply with the requirements of 214 to 217. In order that the number, type and distribution of anodes may be examined, a specification is to be submitted and is to include the following information:—

- (i) Anode material and capacity of anode material.  
*See 218 and 219.*
- (ii) Area of tank structure used in the calculations.
- (iii) Size and shape of anodes, including the cross-sectional area, and gross weight.

(iv) Types of cargo to be carried.

As the protection afforded by anodes cannot be restricted to certain surfaces, the effect of uncoated surfaces adjacent to those which require protection (e.g. tank fittings) must be taken into account when assessing cathodic protection requirements.

**Selective Corrosion Control Scheme for use in Crude Oil Carriers using Defined Ballasting**

225 Where corrosion control is adopted for ships intended solely for the carriage of crude oil, reductions of scantlings in accordance with Table D 2.1 will be permitted provided the requirements given below are fulfilled and the protection system complies with Table D 2.2.

Provided the corrosion control scheme is appropriate to the proposed ballast conditions for the ship, the notation “(cc) crude oil—defined ballasting” will be entered in the *Register Book*.

The Owners or Builders will be required to affirm that the ship is intended solely for the carriage of crude oil and that they are willing to accept the above notation, and the associated restrictions on ballasting.



TABLE D 2.2

	COATINGS	CATHODIC PROTECTION
Ballast Tanks	All surfaces	Anodes below normal liquid level plus coating of all surfaces above normal liquid level ( <i>see</i> Note 1)
Crude Oil/ Ballast Tanks	All surfaces above the normal ballast or cargo level ( <i>see</i> Notes 1 and 2) plus the upper surface of all horizontal items in remainder of the tank—also the bottom shell, bottom longitudinals and girders up to the level of the top of the longitudinals	Anodes below normal ballast or cargo level plus coating of all surfaces above normal liquid level ( <i>see</i> Notes 1 and 2)
Crude Oil only Tanks	All surfaces above the normal liquid level ( <i>see</i> Notes 1 and 2), bottom shell, bottom longitudinals and girders up to the level of the top of the longitudinals	Not applicable

## NOTES

1. The minimum coating is to be all the surfaces in the top 1,5 m of the tank.
2. For inert gas systems, *see* 226.

**Inert Gas Systems**

226 Where an inert gas system is installed and tested in accordance with E 1160 to E 1184 and the notation "IGS" entered in the *Register Book*, then the coating requirement at the top of cargo or cargo/ballast tanks may be omitted on the understanding that the system will be operated on a continuous basis.

**Fitting of Ceiling in Holds**

227 Ceiling is to be laid on the inner bottom of dry cargo ships under hatchways and over bilges, where it is to be fitted with readily removable portable sections. The spaces between frames at the top of the bilge ceiling are to be closed by wood chocks, cement or other suitable means.

228 Ceiling may be omitted provided the inner bottom plating is increased by 5 mm in the case of Type 1 ships or 2 mm in the case of Type 2 ships. For the definitions of Types 1 and 2 ships, *see* D 318.

229 It is recommended that in any ship which is regularly to be discharged by grabs, the increase in thickness of the inner bottom plating should be not less than 5 mm and the plating be fitted with a flush surface. Alternatively, double ceiling should be fitted.

230 Ceiling is to be laid either directly on the inner bottom plating embedded in a suitable composition or on

battens providing a clear space of at least 12,5 mm for drainage.

The thickness of wood ceiling is not to be less than 65 mm. Where it is intended to use plywood or other forms of ceiling of an approved type instead of planking, the thickness will be considered for each case.

231 Where the covers or fittings of the manholes in the inner bottom project above the plating, they are to be protected by a steel coaming around each manhole, fitted with a hatch of wood or steel.

**Cargo Battens in Holds**

232 Where cargo battens or equivalent are fitted in the holds of dry cargo ships, the descriptive notation "SF" will be entered in the *Register Book*.

233 The battens, when fitted, are to extend from above the upper part of the bilge to the underside of beam knees in the holds, and in all cargo spaces in the 'tween decks and superstructures up to the underside of beam knees.

234 Wood cargo battens are to be not less than 50 mm in thickness and the clear space between adjacent rows is, in general, not to exceed 230 mm. The dimensions and spacing of battens made of other materials will be considered. Nets may be adopted in lieu of battens, and other alternative proposals will be specially considered.

235 For arrangements in way of refrigerated holds, see N 415 and N 416.

### Deck Coverings

236 Where plated decks are sheathed with wood or approved composition, reductions in plate thickness may be allowed. See D 425.

The steel deck is to be coated with a suitable material in order to prevent corrosive action, and the sheathing or composition is to be effectively secured to the deck.

237 Deck coverings are to be of a type which will not readily ignite where used on decks:

- (a) forming the crown of machinery or cargo spaces within accommodation spaces of cargo ships,
- (b) within accommodation spaces, control stations, stairways and corridors of passenger ships.

### Section 3

#### ASSESSMENT OF LONGITUDINAL STRENGTH

#### Symbols

301  $L$  = length of ship, in metres,

$L_{pp}$  = the distance, in metres, on the summer load waterline from the fore side of the stem to the after side of the rudder post, or to the centre of the rudder stock if there is no rudder post. In ships with unusual stern arrangements, the length  $L_{pp}$  will be specially considered.

$B$  = breadth of ship, in metres,

$D$  = depth of ship, in metres,

$C_b$  = moulded block coefficient at load draught, **AMENDED SEE NOTICE No. 3.** ~~but is not to be taken less than 0.50.~~ The block coefficient is to be determined using the length  $L$ .

$I$  = the actual inertia, in  $\text{cm}^4$ , of the hull midship section about the horizontal neutral axis,

$y$  = the vertical distance, in metres, from the neutral axis to the moulded deck line at side, or to the line of top of keel, as appropriate,

$\left(\frac{I}{y}\right)_m$  = the minimum hull midship section modulus, in  $\text{cm}^3$ , see 319,

$\frac{I}{y}$  = the design hull midship section modulus, in  $\text{cm}^3$ , to deck or bottom as appropriate,

$k$  = higher tensile steel factor, see D 116,

$M_w$  = the Rule wave bending moment amidships, in  $\text{kN m}$  (tonne-f m),

$M_s$  = the design still water bending moment, in  $\text{kN m}$  (tonne-f m),

$F_w$  = the Rule wave shear force, in  $\text{kN}$  (tonne-f),

$F_s$  = the design still water shear force, in  $\text{kN}$  (tonne-f),

$V$  = maximum service speed, in knots, with the ship in the loaded condition,

$\sigma_s$  = the Rule still water bending stress, in  $\text{N/mm}^2$  ( $\text{kgf/mm}^2$ ),

$\sigma_w$  = the Rule wave bending stress, in  $\text{N/mm}^2$  ( $\text{kgf/mm}^2$ ),

$\sigma_c$  = the Rule combined stress ( $\sigma_s + \sigma_w$ ), in  $\text{N/mm}^2$  ( $\text{kgf/mm}^2$ ).

#### General

302 Longitudinal strength calculations are to be made covering the range of load and ballast conditions proposed for the ship in order to determine the required minimum hull midship section modulus and, where applicable, the shear forces which will be imposed on the hull structure.

303 The requirements of this Section apply to sea-going ships of normal form, proportions and speed unless direct calculation procedures are adopted, in which case the assumptions made and the calculations performed are to be submitted for approval. For ships with restricted service notations, consideration will be given to proposals for a suitably reduced hull section modulus.

304 Individual consideration based on direct calculation procedures will generally be required for ships having one or more of the following characteristics:—

- (a) Length  $L$  greater than 400 m.
- (b) Speed  $V$  greater than that defined in Table D 3.1, for the associated block coefficient.
- (c) Unusual type or design.
- (d) Unusual hull weight distribution.
- (e)  $\frac{L}{D}$  greater than 17,  $\frac{L}{B}$  less than 5, or  $\frac{B}{D}$  greater than 2.5.
- (f) Large deck openings (see 305) or when warping stresses in excess of  $14.7 \text{ N/mm}^2$  ( $1.5 \text{ kgf/mm}^2$ ) are likely to occur. (See 323 and 341).
- (g) Openings for side loading in way of both sheerstrake and stringer.

(h)  $C_b$  LESS THAN 0.6 (NOTICE No. 3)



SEE NOTICE No 3  
FOR NEW TABLE D 3.1

LENGTH L	$C_b$	SPEED V
200 m or less	$> 0,80$	17
	$= 0,65$	20
	$< 0,50$	25
over 200 m	$> 0,80$	18
	$= 0,65$	23
	$< 0,50$	28

NOTE. Speed for intermediate values of  $C_b$  to be obtained by linear interpolation.

305 A ship is regarded as having large deck openings if both the following conditions apply to any one opening:—

- (a)  $\frac{b}{B_1} > 0,6$   
 (b)  $\frac{l_H}{l_{BH}} > 0,7$

where  $b$  = breadth, in metres, of the opening. Where there are multiple openings abreast, these are regarded as a single opening, and  $b$  is to be the sum of the individual widths of these openings.

$B_1$  = extreme breadth, in metres, of deck, including opening, measured at the mid-length of the opening.

$l_H$  = length, in metres, of the opening,

$l_{BH}$  = distance, in metres, between centres of the deck strip at each end of the opening. Where there is no further opening beyond the one under consideration, the point to which  $l_{BH}$  is measured will be considered.

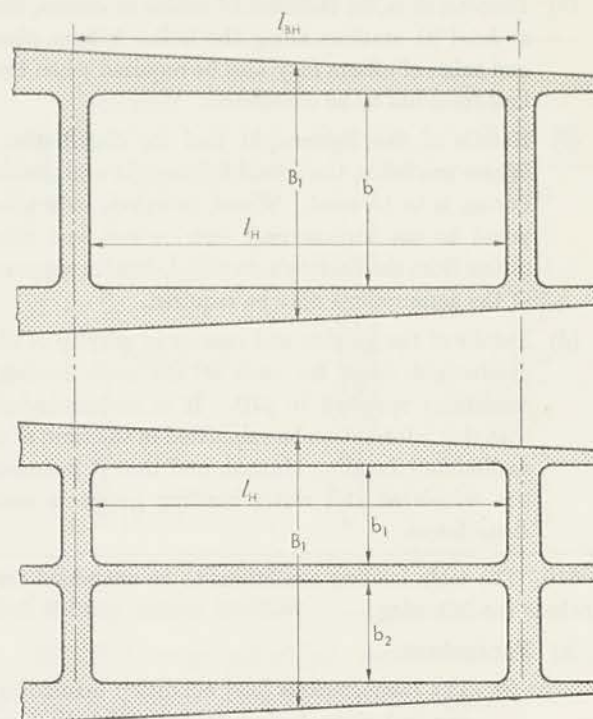
See also Fig. D 3.1.

306 For the purpose of longitudinal strength calculations, the ship is to be divided into 21 stations based on the length between perpendiculars,  $L_{pp}$ , such that:—

- Station 0 is at the aft perpendicular,  
 Station 10 is at the middle of  $L_{pp}$ , and  
 Station 20 is at the fore perpendicular.

#### Erections Contributing to Hull Strength

307 Where a long superstructure or deckhouse is fitted extending within the  $0,5L$  amidships, the requirements for longitudinal strength in the hull and erection will be considered in each case.



$$b = b_1 + b_2$$

FIG. D 3.1

#### Direct Calculation Procedures

308 Direct calculation procedures capable of deriving the wave induced loads on the ship, and hence the required modulus, are to take into account the ship's actual form and weight distribution.

The Society's direct calculation method involves derivation of response to regular waves by strip theory, short-term response to irregular waves using the sea spectrum concept and long-term response predictions using statistical distributions of sea states. Other direct calculation methods submitted for approval should normally contain these three elements and produce similar and consistent results when compared with the Society's method.

#### Information Required

309 In order that an assessment of the longitudinal strength requirements can be made, the following information is to be submitted, in the Society's standard format where appropriate:—

- (a) General arrangement and capacity plan or list, showing details of the volume and position of centre of gravity of all tanks and compartments.



- (b) Bonjean data, in the form of tables or curves, for at least 21 stations along the hull. A lines plan and table of offsets may also be required when the hull form has to be considered.
- (c) Details of the lightweight and its distribution. Where available, the actual lightweight and distribution is to be used. Where, however, it is proposed to use an assumed distribution, and this differs from the Society's standard, data in support of the assumptions may be required.
- (d) Details of the weights and centres of gravity of all deadweight items for each of the main loading conditions specified in 310. It is recommended that this information be submitted in the form of a preliminary Loading Manual, and that it includes the calculated still water bending moments and shear forces.

**310** The main loading conditions to be examined are to include the following:—

- (a) For tankers.
  - (i) The homogeneous load condition (excluding dry and clean ballast tanks) and ballast or part-loaded conditions for both departure or arrival.
  - (ii) Any specified non-uniform distributions of loading.
  - (iii) Mid-voyage conditions relating to tank cleaning or other operations where these differ significantly from the ballast conditions.
- (b) Other types of ship.
  - (i) The homogeneous and, if applicable, non-homogeneous load and part-loaded conditions, including conditions with deck loading, and the ballast conditions. The calculations are to cover both departure and arrival conditions.
  - (ii) Details of the specified loading where a class notation is desired permitting certain holds to be empty.
  - (iii) Details of the proposed depths of liquid where water ballast or liquid cargo is proposed to be carried in the holds.
  - (iv) Loading conditions for short, or sheltered water, voyages where higher still water bending moments are desired.
  - (v) Details of mid-voyage ballasting or other proposed changes in the loading conditions.

**311** Further information may be required when direct calculation procedures are adopted.

#### Approved Calculation Systems

**312** Where the assumptions, method and procedures of a longitudinal strength calculation system have received general approval from the Society, calculations using the system for a particular ship may be submitted.

#### Design Bending Moment

**313** The Rule hull midship section modulus is to be determined from the design bending moment in association with a maximum permissible stress which depends on the type of ship.

The design bending moment is to be taken as the sum of still water and wave bending moment components which are derived as follows.

**314** The design still water bending moment,  $M_s$ , is the maximum moment, hogging or sagging, calculated for all the loading conditions given in 310.

**315** The Rule wave bending moment,  $M_w$ , is calculated at amidships and is given by the expression:—

$$M_w = \sigma_w C_1 L^2 B (C_b + 0.7) \times 10^{-3} \text{ kN m (tonne-f m)}$$

where  $C_1$  has the values given in Table D 3.2 and  $\sigma_w$  has the values given in Table D 3.4.

**316** Where the wave bending moment is required at other positions along the length of the ship, the amidship value may be multiplied by the factors given in Table D 3.3. These factors are based on the Froude Number,  $F_n$ ,

$$\text{which is defined as } \frac{0.164V}{\sqrt{L_{pp}}}$$

For intermediate values of  $F_n$  the factor is to be determined by linear interpolation, and for values greater than 0.3, linear extrapolation is to be used.

#### Maximum Permissible Stresses

**317** The permissible stress to be used in the calculation of hull section modulus is the combined stress,  $\sigma_c$ , given in Table D 3.4 for the appropriate ship type.

If higher tensile steel is used, see 325 and 326.

**318** Ship types for Table D 3.4 are distinguished as follows:—

##### Type 1

Ships for the carriage of bulk liquid cargoes (e.g. oil tankers, ore or oil and OBO carriers, etc., but excluding liquefied gas carriers).



Ships for the carriage of bulk dry cargoes such that the loading (in at least one hold or compartment) is denser than that corresponding to a stowage rate of 1 m<sup>3</sup>/tonne.

### Type 2

General and miscellaneous cargo ships.

Ships for the carriage of bulk dry cargoes such that the loading in each hold or compartment is less dense than that corresponding to a stowage rate of 1 m<sup>3</sup>/tonne.

Liquefied gas carriers.

The stowage rate is defined as the volume of the hold or compartment (excluding the hatchway) divided by the weight of cargo stowed therein.

In general, proposals to use one hold or equivalent compartment as a water ballast tank need not be taken into account in determining ship type.

The requirements for ships of special or unusual design and for the carriage of special cargoes will be individually considered, *see* 304.

TABLE D 3.2

LENGTH L	FACTOR C <sub>1</sub>
m	
90	7,840
100	8,040
125	8,473
150	8,913
over 150 and not exceeding 300	$C_1 = 10,75 - \left(\frac{300-L}{100}\right)^{1,5}$
over 300 and not exceeding 350	10,75
375	10,69
400	10,63

NOTE. Intermediate values of C<sub>1</sub> to be obtained by linear interpolation.

TABLE D 3.3

POSITION	FACTOR	
	F <sub>n</sub> ≤ 0,20	F <sub>n</sub> = 0,30
Station 0 (A.P.)	0,00	0,00
2	0,14	0,14
4	0,30	0,30
6	0,58	0,58
8	0,87	0,87
10 (mid-L <sub>pp</sub> )	1,00	1,00
12	0,90	0,95
14	0,68	0,80
16	0,41	0,62
18	0,20	0,33
20 (F.P.)	0,00	0,00

### Hull Midship Section Modulus

319 The design hull midship section modulus  $\frac{I}{y}$  is not to be less than the greater of the following values:—

$$(a) \frac{I}{y} = \left(\frac{I}{y}\right)_m$$

$$\text{where } \left(\frac{I}{y}\right)_m = C_1 L^2 B (C_b + 0,7) \text{ cm}^3$$

and C<sub>1</sub> is defined in Table D 3.2, AND C<sub>b</sub> IS NOT TO BE TAKEN LESS THAN 0,60. SEE NOTICE No. 3

$$(b) \frac{I}{y} = \frac{M_s + M_w}{\sigma_c} \times 10^3 \text{ cm}^3$$

where M<sub>w</sub>, M<sub>s</sub> and σ<sub>c</sub> are in appropriate units, *see* 301.

### Still Water Bending Moments—Special Consideration

320 For sea-going service (*see* Table D 3.4), for any loading condition where the maximum design still water bending moment, M<sub>s</sub>, exceeds 0,8 M<sub>w</sub> for Type 1 ships or 1,0 M<sub>w</sub> for Type 2 ships, the design hull midship section modulus is to be not less than:—

For Type 1 ships

$$\frac{I}{y} = \left(\frac{2}{3\sigma_s} (M_s - 0,8 M_w) + \frac{1,8 M_w}{\sigma_c}\right) \times 10^3 \text{ cm}^3$$

For Type 2 ships

$$\frac{I}{y} = \left(\frac{2}{3\sigma_s} (M_s - M_w) + \frac{2 M_w}{\sigma_c}\right) \times 10^3 \text{ cm}^3$$

where M<sub>w</sub>, M<sub>s</sub>, σ<sub>s</sub> and σ<sub>c</sub> are in appropriate units, *see* 301.

TABLE D 3.4

SHIP TYPE	$\sigma_c$	SEA-GOING SERVICE		SHELTERED WATER SERVICE		SHORT VOYAGES	
		$\sigma_s$	$\sigma_w$	$\sigma_s$	$\sigma_w$	$\sigma_s$	$\sigma_w$
TYPE 1	160,8 (16,40)	62,8 (6,4)	98,1 (10,0)	111,8 (11,4)	49,0 (5,0)	82,4 (8,4)	78,5 (8,0)
TYPE 2	178,0 (18,15)	79,9 (8,15)	98,1 (10,0)	129,0 (13,15)	49,0 (5,0)	99,5 (10,15)	78,5 (8,0)

NOTE. Units of stress are N/mm<sup>2</sup> (kgf/mm<sup>2</sup>).

### Stress at Deck and Bottom

321 The maximum stresses due to longitudinal bending at the deck and bottom are given by:—

$$\sigma_{\text{deck}} = \left( \frac{M_s + M_w}{\left( \frac{I}{y} \right)_{\text{deck}}} \right) \times 10^3 \text{ N/mm}^2 \text{ (kgf/mm}^2\text{)}$$

$$\sigma_{\text{bottom}} = \left( \frac{M_s + M_w}{\left( \frac{I}{y} \right)_{\text{bottom}}} \right) \times 10^3 \text{ N/mm}^2 \text{ (kgf/mm}^2\text{)}$$

where  $\left( \frac{I}{y} \right)_{\text{deck}}$  and  $\left( \frac{I}{y} \right)_{\text{bottom}}$  are the actual section moduli of the hull, in cm<sup>3</sup>, and  $M_w$  and  $M_s$  are in appropriate units, see 301.

When the section modulus to deck or bottom is the minimum permitted by 319, the corresponding stress is equal to  $\sigma_c$ .

### Short Voyages and Sheltered Water Service

322 For short voyages and sheltered water service, the still water bending moment may be increased by using  $\sigma_s$  as given in Table D 3.4. That is:—

$$M_s = \sigma_s \times \frac{I}{y} \times 10^{-3} \text{ kN m (tonne-f m)}$$

The loading conditions are to appear in the Loading Manual.

"Short voyages" are defined as voyages not exceeding 24 hours in duration, in reasonable weather.

"Reasonable weather" and "sheltered water" are defined in B 105.

### Open Type Ships

323 For ships other than container ships, having large deck openings (see 305), or where warping stresses in excess of 14,7 N/mm<sup>2</sup> (1,5 kgf/mm<sup>2</sup>) are likely to occur, local increases in section modulus within 0,4L amidships may be required and this will influence the maximum Rule still water bending stress.

Where such reinforcement is not required, the Rule stresses are to comply with ship Type 2 of Table D 3.4. For calculations for container ships, see 341 and subsequent paragraphs.

### Fast Cargo Ships

324 In ships of length between 120 and 170 m and service speed greater than 17,5 knots, in association with a bow shape factor of more than 0,15 (see D 124), the Rule hull midship section modulus and the distribution of longitudinal material in the forward half-length will be considered.

In general, the following requirements are to be complied with:—

- The vertical hull midship section modulus, about the horizontal neutral axis, is to be not less than  $331 L \Sigma A_b \text{ cm}^3$ , or that required by 319, whichever is the greater.  $\Sigma A_b$  is defined in D 124.
- The horizontal hull midship section modulus, about a vertical axis through the ship centreline, is to be not less than  $32,5 L^2 D \text{ cm}^3$ .
- In the forward half-length, the section modulus is not to be a lesser percentage of the midship value than shown in Table D 3.5.
- Any load or ballast condition resulting in a sagging still water bending moment, or a hogging moment less than 80 per cent of the Rule value of still water



bending moment will be specially considered with a view to minimizing the compressive stresses in the deck in waves.

TABLE D 3.5

POSITION	PERCENTAGE OF VERTICAL MODULUS	PERCENTAGE OF HORIZONTAL MODULUS
Station 10	100	100
12	98	87
14	95	62
16	81	38
18	44	17

NOTE. Intermediate values to be obtained by interpolation.

#### Modulus Correction for Higher Tensile Steel

325 Where higher tensile steel is used in the main hull structure, the hull midship section modulus as determined above is to be multiplied by the factor  $k$ , or by  $0,059 \frac{L}{D}$ , whichever is the greater.

The higher tensile steel is to be used for the whole of the longitudinal continuous material at least to a distance  $(1-k)y$  or  $\left(1 - 0,059 \frac{L}{D}\right)y$ , whichever is the lesser, from the line of deck at side or keel.

326 Where higher tensile steel is proposed for the topsides only, the hull section modulus at deck is to be

multiplied by the factor  $k$ , or by  $\frac{0,059 \frac{L}{D}}{2 - 0,059 \frac{L}{D}}$ , whichever is the greater.

The higher tensile steel is to be used for the whole of the longitudinal continuous material at least to a distance

$$(1-k)y \quad \text{or} \quad \left(1 - \left(\frac{0,059 \frac{L}{D}}{2 - 0,059 \frac{L}{D}}\right)\right)y$$

below the line of deck at side, whichever is the lesser.

#### Calculation of Hull Section Modulus

327 All continuous longitudinal material is to be included in the calculation of the inertia of the hull midship section, and the lever,  $y$ , is to be measured vertically from the neutral axis to the top of keel and to the moulded deck line at side.

328 Lightening holes in girders need not be deducted, provided their depth does not exceed 20 per cent of the web depth.

Isolated weld scallops and drain and air holes in longitudinals need not be deducted, provided their depth does not exceed 10 per cent of the web depth, nor 75 mm, whichever is the greater. Such openings are considered isolated if they are spaced not less than 1 to 1,5 m apart.

329 In general, isolated deck openings need not be deducted, but compensation may be required, see D 408.

330 Where continuous hatch coamings are arranged, 80 per cent of the area of the coaming may be included in the calculation of hull section modulus, and the lever,  $y$ , is to be measured:—

- to the moulded deck line at side amidships,
- to a point a distance above the moulded deck line at side amidships equal to the height of the hatch coaming above the deck.

The hull section modulus with  $y$  measured as in (a) is to be 5 per cent greater, and as in (b) may be 10 per cent less, than that required by 319.

331 Where two or more hatchways are arranged abreast, the percentage of the material between hatchways to be included in the section modulus will be considered. Individual consideration will also be given to other special or unusual designs.

#### Shear Forces

332 The shear forces on the hull structure are to be investigated for all ships of the two longitudinal bulkhead design and for other types where any non-homogenous loading conditions are proposed.

The Rule wave shear force,  $F_w$ , at any position along the ship is given by:—

$$F_w = e^{-0,0035L} K_1 K_2 B L^2 (C_b + 0,70) \times 10^{-5} \text{ kN (tonne-f)}$$

where

- $$K_1 = 0 \text{ at Station 0,}$$
- $$= 2216 \text{ (226) between Stations 5 and 7,}$$
- $$= 1383 \text{ (141) between Stations 9 and 11,}$$
- $$= 2314 \text{ (236) between Stations 15 and 17,}$$
- $$= 0 \text{ at Station 20.}$$

Intermediate values to be determined by linear interpolation.

- $$K_2 = 1,0 \text{ for sea-going service conditions,}$$
- $$= 0,5 \text{ for sheltered water service conditions,}$$
- $$= 0,8 \text{ for short voyage service conditions.}$$

For reference purposes, values of  $L^2 e^{-0,0035L} \times 10^{-5}$  are given by the factor in Table D 3.6.

TABLE D 3.6

L	FACTOR	L	FACTOR
90	0,059 11	260	0,272 11
100	0,070 47	280	0,294 24
120	0,094 61	300	0,314 94
140	0,120 07	320	0,334 11
160	0,146 23	340	0,351 68
180	0,172 56	360	0,367 62
200	0,198 63	380	0,381 91
220	0,224 10	400	0,394 56
240	0,248 67		

**333** The actual still water shear force at each transverse section along the hull is the maximum value found from the longitudinal strength calculations for each of the loading conditions specified in 309.

The design still water shear force is to be calculated as given below, and the thickness of material increased if necessary such that the value is not less than the actual still water shear force.

**334** Where no longitudinal bulkhead is fitted, the design still water shear force is given by:—

$$F_s = \frac{118 I_1 t_1}{100 A\bar{y}} - F_w \text{ kN}$$

$$\left( F_s = \frac{12 I_1 t_1}{100 A\bar{y}} - F_w \text{ tonne-f} \right)$$

In this expression:—

- $t_1$  = the combined thickness, in mm, of side shell, for both sides of the ship, at the neutral axis. Special consideration will be given to the inclusion of the effective thickness of any partial longitudinal bulkhead, depending on the arrangements of the structure.
- $I_1$  = the inertia, in  $\text{cm}^4$ , of the hull about the horizontal neutral axis at the section concerned.
- $A\bar{y}$  = the first moment of area, in  $\text{cm}^3$ , of the longitudinal material above the neutral axis at the section concerned.
- For ships of normal form and conventional structural design, the values of  $A\bar{y}$  and  $I$  for the midship section may be used for the calculation of shear stress at any point along the length of the ship.
- The actual shear force obtained from the longitudinal strength calculations may be corrected for the

effect of local forces at the transverse bulkhead, it applicable. The calculation of these local forces is to be submitted for approval. Alternatively, the proportion of the load carried by the transverse bulkhead may be taken as

$$\frac{k_3}{k_2 \frac{I}{b} + k_3}$$

where these terms are defined in D 942.

**335** Where double skin construction of the side shell is proposed, shear flow calculations may be required to be submitted.

**336** Where two longitudinal bulkheads are fitted, the design still water shear force is generally given by the following expressions, but where the transverse distribution of load is non-uniform the shear forces in the longitudinal bulkhead and side shell may require to be examined by direct calculation procedures.

(a) In the shell plating

$$F_s = \frac{118 t_2 D}{0,16 + 0,075 \frac{A_s}{A_L}} - F_w \text{ kN}$$

$$\left( F_s = \frac{12 t_2 D}{0,16 + 0,075 \frac{A_s}{A_L}} - F_w \text{ tonne-f} \right)$$

(b) In the longitudinal bulkheads

$$F_s = \frac{118 t_3 D}{0,34 - 0,075 \frac{A_s}{A_L}} - F_w \text{ kN}$$

$$\left( F_s = \frac{12 t_3 D}{0,34 - 0,075 \frac{A_s}{A_L}} - F_w \text{ tonne-f} \right)$$

In these expressions

- $t_2$  = the thickness, in mm, of the side shell at the section concerned, at the neutral axis,
- $t_3$  = the minimum thickness, in mm, of the longitudinal bulkhead plating at the section concerned within the 0,5D about mid-depth. Outside this range, no part of the bulkhead plating is to be less in thickness than 0,9 $t_3$  mm,
- $A_s$  = the area of side shell, in  $\text{cm}^2$ , at the section concerned, taken as the plating area over a depth equal to D,



$A_L$  = the area of longitudinal bulkhead plating, in  $\text{cm}^2$ , at the section concerned, taken as the sum of plating areas from bottom to deck.

- (b) Where it is necessary to increase the thickness of the side shell or longitudinal bulkhead to meet these requirements, the original thicknesses are to be used in the calculation of the cross-sectional areas  $A_S$  and  $A_L$ .

337 The calculation of shear forces immediately beyond the ends of the longitudinal bulkheads will be considered in relation to the arrangement of structure in these regions.

338 The above shear force calculations are based upon a maximum Rule combined shear stress of  $117,7 \text{ N/mm}^2$  ( $12,0 \text{ kgf/mm}^2$ ).

339 Where more than two longitudinal bulkheads are fitted, direct calculation procedures are to be adopted, based on shear flow theory or an equivalent method.

#### Loading Manual and Loading Instruments

340 The Loading Manual is to be submitted for approval in respect of longitudinal strength for all ships.

The Manual is to contain details of the proposed load, ballast and part-loaded conditions, subdivided into departure and arrival conditions. Where applicable, the Manual is also to contain details of any other loading conditions for which the hull scantlings have been approved (*see also* 309).

Where non-homogenous loading conditions are proposed, or where it is likely that service conditions significantly different from those for which the scantlings were approved may arise, it is recommended that an approved means of determining the suitability of loading be placed on board the ship. Proposals to use such means will be specially considered, with particular reference to the suitability to the type of vessel and its intended service.

#### Combined Stress Calculations for Container Ships

##### General

341 The primary longitudinal strength of container ships having double skin construction or single skin construction in association with torsion box girders is to be examined using a combination of bending and torsional stress resultants when one or more of the following conditions apply:—

$$(a) \frac{b}{B_1} \geq 0,7$$

$$(b) \frac{l_H}{l_{BH}} \geq 0,89$$

$$(c) \frac{b}{B_1} > 0,6 \text{ and } \frac{l_H}{l_{BH}} > 0,7$$

where these terms are defined in 305 and illustrated in Fig. D 3.1.

342 Direct calculation procedures using the methods outlined in 308 and applying long term prediction methods may also be used.

343 Where other arrangements of primary structure are proposed, or where new or unusual design features are to be incorporated, direct calculations will be required.

344 Special consideration will be given to ships having hatch openings of width greater than  $0,85B$ , where the average rate of torsional deformation exceeds  $0,006$  degrees per metre, or where the elongation of the hatch opening diagonal under standard torque loading exceeds  $35 \text{ mm}$ .

#### Symbols and Definitions

345 In addition to the symbols defined in 301, the following terms are used:—

SWBM = the maximum still water bending moment, in  $\text{kN m}$  (tonne-f m), at the section under consideration, determined from the envelope embracing all the still water bending moments derived from the longitudinal strength calculations (*see* 310). All the proposed loading conditions are to be included.

VWBM = the design vertical wave bending moment, in  $\text{kN m}$  (tonne-f m), in a head sea, at the section under consideration. The value of VWBM at the middle of  $L_{pp}$  is given by:—

$$0,981 C_0 L^2 B (C_{b_1} + 0,7) \text{ kN m} \\ (0,1 C_0 L^2 B (C_{b_1} + 0,7) \text{ tonne-f m}).$$

$$\text{where } C_0 = 0,6 + 0,0942 \left( \frac{L}{100} - 1 \right)$$

$C_{b_1}$  = moulded block coefficient at load draught, but is not to be taken less than  $0,6$ . The block coefficient is to be determined using the length  $L$ .

The distribution of VWBM along the length of the ship is given in Table D 3.7.

HWBM = the design horizontal wave bending moment in  $\text{kN m}$  (tonne-f m), at the section under



consideration. The value of HWBM at the middle of  $L_{pp}$  is given by:—

$$\text{HWBM} = 0,431 L^2 B \text{ kN m}$$

$$(\text{HWBM} = 0,044 L^2 B \text{ tonne-f m})$$

The distribution of HWBM along the length of the ship is given in Table D 3.7.

$T$  = the torque amidships, in kN m (tonne-f m), given by:—

$$9,81e^{-0,00295L} \frac{LB^3 C_T}{10\,000} \left(1,75 + 1,5 \frac{\varepsilon}{D}\right) \text{ kN m}$$

$$\left(e^{-0,00295L} \frac{LB^3 C_T}{10\,000} \left(1,75 + 1,5 \frac{\varepsilon}{D}\right) \text{ tonne-f m}\right)$$

$$\text{where } C_T = 13,2 - 43,4C_w + 78,9C_w^2$$

$C_w$  = the water plane area coefficient, but need not exceed  $0,165 + 0,95 C_{b1}$ .

$\varepsilon$  = the distance, in metres, of the shear centre below the base line of the ship.

The distribution of  $T$  along the length of the ship is to follow a curve of  $(1 - \cos \alpha)$  form where  $\alpha$  is a periodic function of  $L$ .

$T_c$  = the cargo torque, in kN m (tonne-f m), created by uneven transverse distribution of weights, consumables or ballast. Except where higher value is specified,  $T_c$  may be taken as:—

$$T_c = 15,7 B n_s n_t \text{ kN m}$$

$$(T_c = 1,6 B n_s n_t \text{ tonne-f m})$$

where  $n_s$  = the number of stacks of containers over the breadth  $B$ ,

$n_t$  = the number of tiers of containers in cargo holds amidships, excluding containers on deck or on the hatch covers,

but  $T_c$  need not be taken more than 24 520 kN m (2500 tonne-f m) at amidships, and is to be distributed along the length of the ship as given in Table D 3.7.

#### Derivation of Stresses

346 The stresses are to be calculated for different positions along the length of the ship at the bottom and at the deck at the level of the top edge of the longitudinal bulkhead.

The stresses corresponding to SWBM and VWBM are to be evaluated from the values of these moments and of the hull section modulus at the section concerned.

TABLE D 3.7

POSITION	DISTRIBUTION FACTORS		
	VWBM		HWBM and $T_c$
	$F_n \leq 0,20$	$F_n = 0,30$	
Station 0 (A.P.)	0,00	0,00	0,0
2	0,14	0,14	0,2
4	0,30	0,30	0,4
6	0,58	0,58	0,6
8	0,87	0,87	0,8
10 (mid- $L_{pp}$ )	1,00	1,00	1,0
12	0,90	0,95	0,8
14	0,68	0,80	0,6
16	0,41	0,62	0,4
18	0,20	0,33	0,2
20 (F.P.)	0,00	0,00	0,0

NOTE. For definition of  $F_n$ , see 316.

The stress corresponding to HWBM is to be obtained from:—

$$\sigma = \frac{3b}{I_H} \text{ HWBM N/mm}^2 \text{ (kgf/mm}^2\text{)}$$

where

$b$  is defined in 305

and  $I_H$  is the inertia in  $\text{cm}^2\text{m}^2$  of the hull, about a vertical axis through the centreline of the ship at the section concerned.

The warping stresses corresponding to  $T$  and  $T_c$  are to be calculated using a method which has received general approval from the Society.

#### Combined Stress Diagrams and Rule Stresses

347 A combined stress diagram, for the head sea condition, is to be prepared, showing the combination of the still water and vertical wave bending stresses.

The stresses at any point along the length of the ship are not to exceed the following values:—

(a) Still water bending stress at deck (from SWBM)

$$\sigma = \frac{88}{k} \times \frac{0,8}{C_{b1} + 0,2} \text{ N/mm}^2$$

$$\left(\sigma = \frac{9}{k} \times \frac{0,8}{C_{b1} + 0,2} \text{ kgf/mm}^2\right)$$

where  $C_{b1}$  is as defined in 345.

AMENDED  
SEE NOTICE No.1.



(b) Combined stress (from SWBM and VWBM)

(i) At deck

$$\sigma = \frac{157}{k} \text{ N/mm}^2 \quad \left( \sigma = \frac{16,0}{k} \text{ kgf/mm}^2 \right)$$

(ii) At bottom

$$\sigma = \frac{137}{k} \text{ N/mm}^2 \quad \left( \sigma = \frac{14,0}{k} \text{ kgf/mm}^2 \right)$$

348 A second combined stress diagram, for the oblique sea condition, is to be prepared, showing the combination of the stresses derived from the following moments and torques:—

SWBM; 60 per cent of VWBM; HWBM; T; T<sub>c</sub>

These stresses are to be combined as shown in Fig.

D 3.2, and in no case is the stress at any point along the length of the ship to exceed

$$\sigma = \frac{157}{k} \text{ N/mm}^2 \quad \left( \frac{16,0}{k} \text{ kgf/mm}^2 \right)$$

#### Area of Topside Material

349 The total cross-sectional area of the topside box girders or equivalent structure, including all effective material within 0,19D of the upper deck but excluding hatch side coamings, over the range of cargo holds is not to be less than 0,15 Δ cm<sup>2</sup>, where Δ is the full load displacement of the ship, in tonnes.

### Section 4

#### DECK PLATING

##### Symbols

401 L = length of ship, in metres,

L<sub>1</sub> = length of ship, in metres, but need not be taken as greater than 190 m,

s = spacing of beams or longitudinals, in mm, but is not to be taken less than

$$470 + \frac{L_1}{0,6} \text{ mm,}$$

S = spacing of girders or transverses, in mm,

M<sub>D</sub> = actual deck modulus, but is not to be taken greater than 1,5 M<sub>D1</sub>,

M<sub>D1</sub> = Rule deck modulus from D 3,

$$F_D = \frac{M_{D1}}{M_D},$$

k = higher tensile steel factor, see D 116.

#### Construction

402 Provision is made for longitudinal or transverse framing at all decks, but for ships exceeding 120 m in length, longitudinal framing is to be adopted at the strength deck, except that special consideration will be given to proposals for transverse framing on ships where the deck width outside line of openings is less than 0,075B port and starboard. Where plating thicknesses exceed 50 mm, Grade E steel will generally be required.

#### STRENGTH DECK

403 The thickness of strength deck plating amidships outside the line of openings is to be that necessary to give the section modulus required by D 3, but it is not to be less than:—

(a) Longitudinal framing.

(i) L ≤ 190 m,

the lesser of:—

$$\frac{s}{1000} \left( 7 + \frac{L}{17} \right) \sqrt{\frac{F_D}{k}} \text{ mm, or } \frac{s}{55\sqrt{k}} \text{ mm,}$$

but not less than

$$\frac{s}{1200} \sqrt{Lk} + 2,5 \text{ mm}$$

(ii) L > 190 m,

the greater of:—

$$\frac{s}{55\sqrt{k}} \text{ mm, or } \frac{s}{1200} \sqrt{Lk} + 2,5 \text{ mm.}$$

(b) Transverse framing.

The lesser of:—

$$\frac{s}{1000} \left( 1 + \left( \frac{s}{S} \right)^2 \right) \left( 10 + \frac{L}{12} \right) \sqrt{\frac{F_D}{k}} \text{ mm,}$$

$$\text{or } \frac{s}{40\sqrt{k}} \text{ mm,}$$

but is not to be less than

$$\frac{s}{910} \sqrt{Lk} + 2,5 \text{ mm}$$

Inside the line of openings, the thickness amidships is not to be less than:—

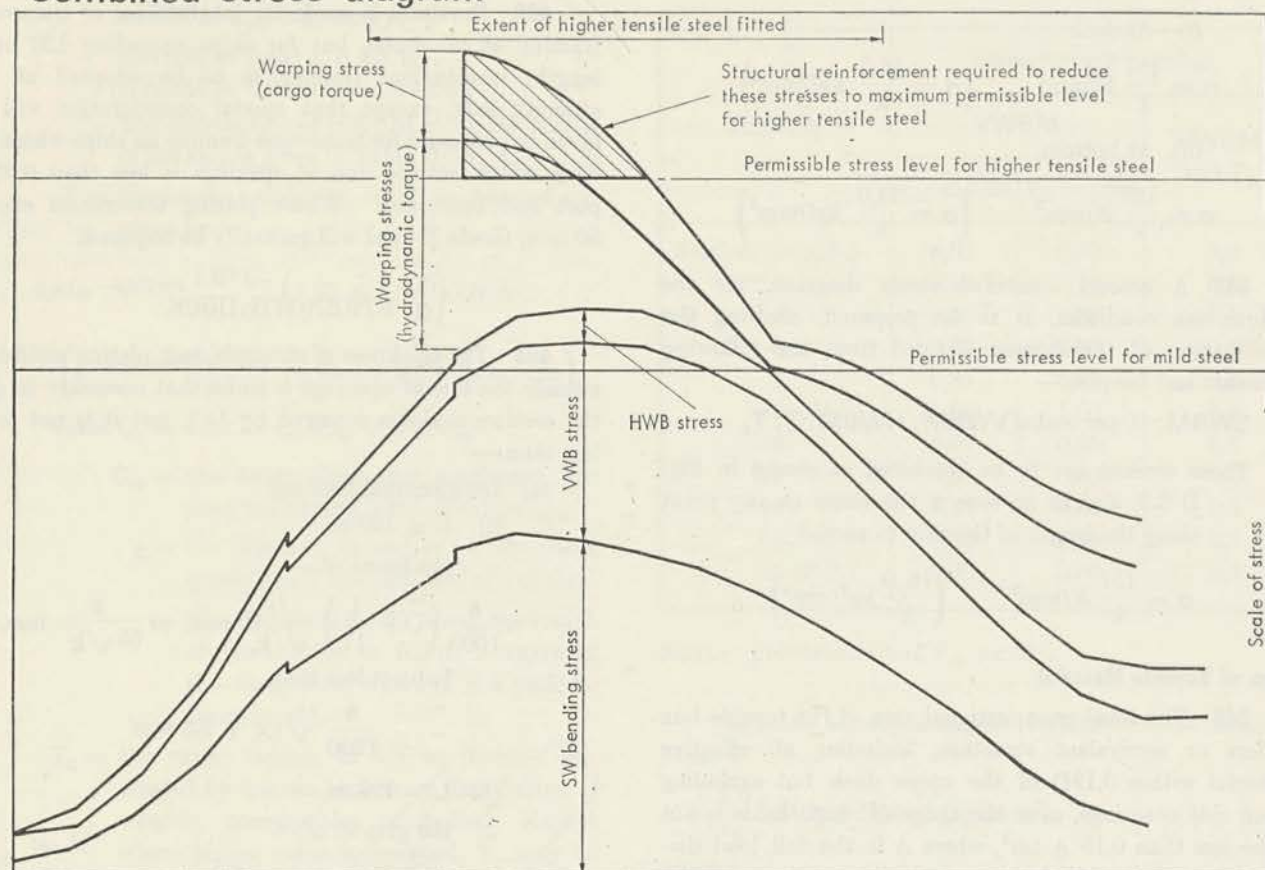
(c) Longitudinal or transverse framing

$$\frac{s}{1200} \sqrt{Lk} + 2,5 \text{ mm}$$

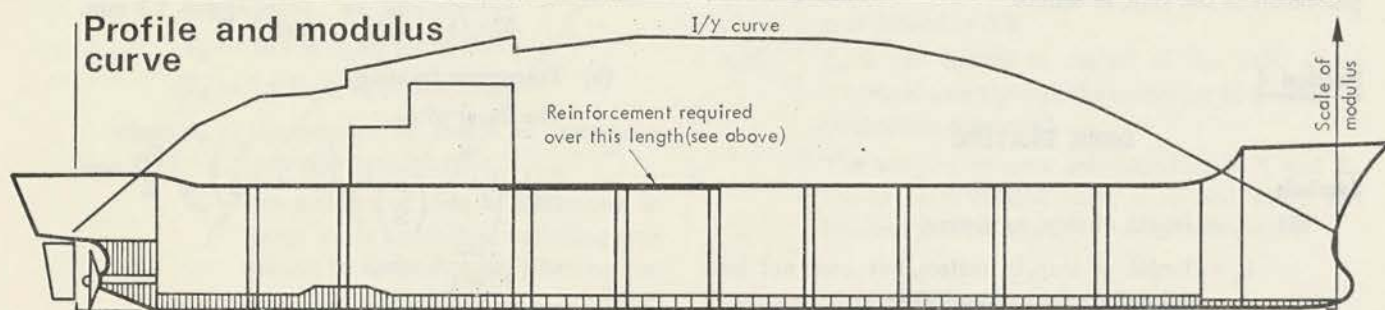
For grades of steel, see 413.

The midship thickness outside line of openings is to be maintained for 0,4L amidships and is to be tapered gradually to the end thickness. See Fig. D 4.1.

## Combined stress diagram



## Profile and modulus curve



## Loading data

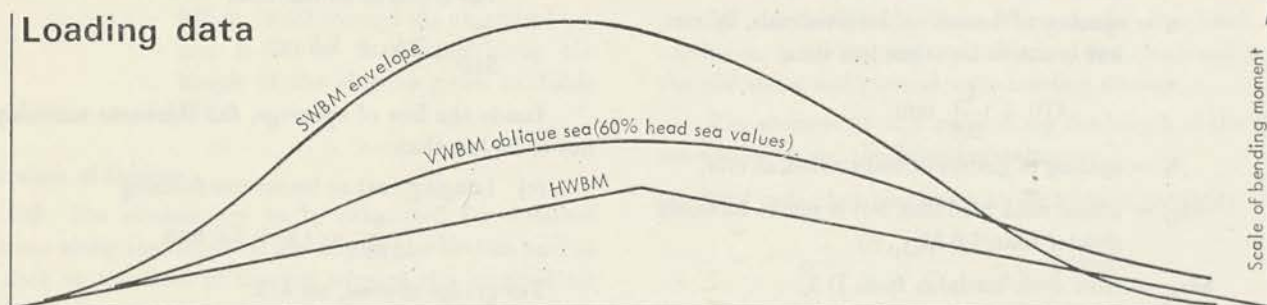


FIG. D 3.2 SAMPLE COMBINED STRESS DIAGRAM FOR OBLIQUE SEA CONDITION.

(NOTE. These diagrams are for illustration only and are not to scale.)



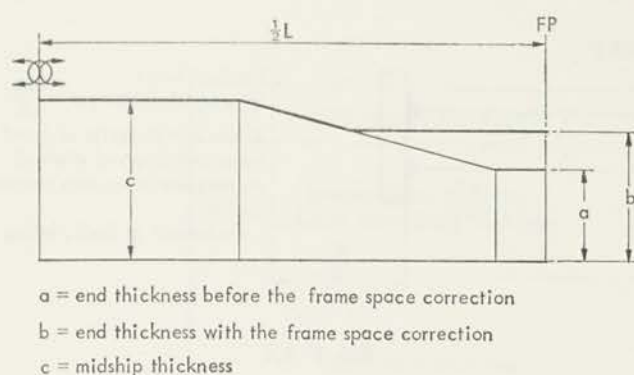


FIG. D 4.1

**404** The thickness of the deck stringer plate is to be increased by 20 per cent at the end bulkheads of bridges, poop and forecastle within  $0,25L$  from amidships. No increase is required if the end bulkhead is outside  $0,3L$  from amidships. The increase at intermediate lengths is to be obtained by interpolation and is to be applied to the tapered thickness of the stringer plate.

#### End Thickness

**405** The thickness of deck plating for  $0,1L$  from the ends is not to be less than:

$$6 + \frac{L}{48} \text{ mm}$$

Where no forecastle is fitted and  $s > 610$  mm, the thickness derived as above is to be increased by a frame space factor, in the ratio  $h_1 \sqrt{\frac{s}{610}}$  for  $0,1L$  from forward,

$$\text{where } h_1 = \frac{D + 2,3 - d}{\text{actual deck height at F.P.}}$$

but  $h_1$  need not be taken greater than 1,0. In no case, however, on ships with no forecastle is the thickness to be less than that required by D 1713.

#### Superstructures

**406** Where a large superstructure or deckhouse is fitted extending within  $0,5L$  amidships, the required thickness of strength deck plating will be considered. See D 307.

#### Strength Deck Openings

**407** Openings in the strength deck outside line of openings should be kept to a minimum and are to be arranged clear of main hatch corners and, wherever possible, clear of one another.

Openings in the strength deck within  $0,5L$  amidships generally, and throughout on open ships, such as container

carriers, between hatch and erection end adjacent to a hatch corner, are to be avoided so far as possible. If they are essential, special consideration is to be paid to their design and Grade E steel may be required in these regions.

**408** In general, compensation will be required to restore the section area, at deck, of the main hull within  $0,5L$  amidships if openings in the strength deck either:—

(a) have a total breadth within any frame space (or between any two transverses in longitudinally framed ships) of more than 6k per cent of the width of deck plating used in the midship modulus calculation, or

(b) cut a deck longitudinal or girder which has been included in the midship modulus calculation.

Outside  $0,5L$  amidships, compensation will not, in general, be required except for openings at the breaks of poops or long forecastles, and also adjacent to hatches and hatch ends on open ships such as container carriers.

Compensation may take the form of increased deck plating thickness, additional deck longitudinals, deck girders of adequate length or other suitable structure.

Where edge reinforcement is required by 411, its area is not to be included when determining the requisite compensation.

**409** Strength deck openings are to be of suitable shape and design to minimize stress concentrations.

The corners of main hatchways are to be elliptical or parabolic in compliance with 410, or are to be rounded with a radius which, for openings within  $0,6L$  amidships, is generally not to be less than  $1/24$  of the breadth of the opening with a minimum of:—

300 mm if the deck plating extends inside the coamings, or

150 mm if the coamings are welded to the inner edge of the plating in a manner similar to the reinforcement required by 411.

**410** If elliptical corners are arranged, the major axis should be fore and aft, the ratio of the major to minor axis should not be less than 2 to 1, and the minimum half-length of the major axis is to be as defined by  $l_1$  in Fig. D 4.2.

Where parabolic corners are arranged, the dimensions should be as shown in Fig. D 4.2.

Where two or more hatchways are arranged abreast, the corner arrangements will be specially considered.

Where the corners of large openings in the strength deck are parabolic or elliptic, insert plates are not required.

For other shapes of corner, insert plates of the size and extent shown in Fig. D 4.3 will be required.



## Required thickness of insert plate:—

Thickness of insert is to be 5 mm greater than deck thickness up to a deck thickness of 25,5 mm. At a deck thickness of 38 mm and above, the increase is to be 4 mm. Between 25,5 and 38 mm, the increase is to be obtained by interpolation. Amended details may be required on open ships.

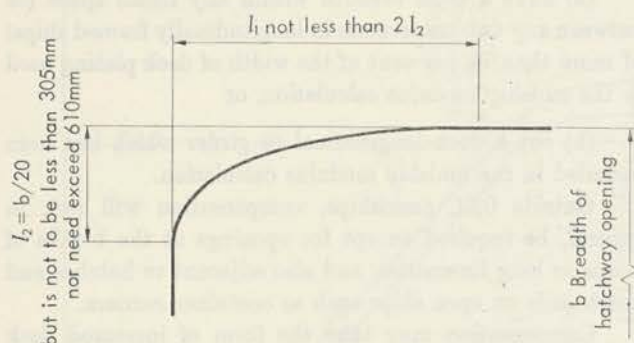


Fig. D 4.2

411 Circular openings and square or rectangular openings with well rounded corners will generally be required to be reinforced, but reinforcement may be omitted for circular openings having a diameter of less than 325 mm, provided that they are situated at a distance from any other opening such that there is an intervening width of plating of not less than five times the diameter of the smaller of the two openings.

Where holes in the strength deck are required to be reinforced, this is generally to be arranged as shown in Fig. D 4.4, but alternative arrangements for edge reinforcement will be considered.

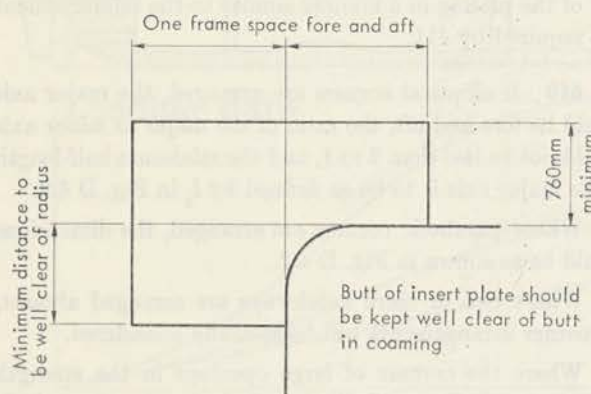


Fig. D 4.3

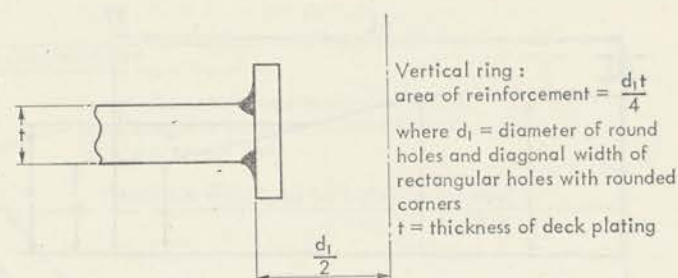


Fig. D 4.4

412 Elliptical openings having their major axes fore and aft and a ratio of length to breadth not less than 2 to 1 will not normally be required to be reinforced, provided that the plate panel in which the opening is cut is itself adequately stiffened against compression and shear buckling.

Openings with square corners or other similar stress raisers will not generally be acceptable.

## Grades of Steel

413 Steel of Grades B and D will generally be required for the strength deck as shown in Table D 4.1.

See also 427 for refrigerated ships, D 1918 for topside tanks, and D 120 for higher tensile steel.

414 In general, any deck plate at a hatch corner exceeding 35,5 mm thickness is to be Grade E or EH steel.

## LOWER DECKS

415 The thickness of plating is not to be less than 6,5 mm nor less than that given below:—

Second deck—outside line of openings and within 0,4L amidships	... $\frac{s}{85}$ mm
Second deck—within line of openings and for 0,1L at ends	... $\frac{s}{100}$ mm
Third deck—outside line of openings and within 0,4L amidships	... $\frac{s}{95}$ mm
Third deck—within line of openings and for 0,1L at ends	... $\frac{s}{100}$ mm
Platform decks	... $\frac{s}{100}$ mm

Where a deck loading exceeding 43,1 kN/m<sup>2</sup> (4,4 tonne-f/m<sup>2</sup>) is contemplated, the thickness of the deck plating will be considered.



TABLE D 4.1

THICKNESS OF PLATING	GRADE OF STEEL
Greater than 20,5mm but not exceeding 25,5 mm	B { (i) For 0,4L amidships (ii) At corners of openings and at breaks of superstructures irrespective of position.
Exceeding 25,5 mm	D { (i) For 0,4L amidships (ii) At corners of openings and at breaks of superstructures irrespective of position (iii) Any stringer plating irrespec- tive of position.

416 Where long wide hatchways are arranged on lower decks, it may be necessary to increase the deck thickness obtained from 415 to ensure effective support for side framing.

#### Lower Deck Openings

417 Openings in lower decks should be kept clear of main hatch corners and other areas of high stress, so far as possible.

Compensation will not, in general, be required unless the total width of openings in any frame space, or between any two transverses, exceeds 15% per cent of the original effective plating width. The requirements of 410 to 412 also apply generally to lower deck openings except that:—

(a) the thickness of inserts, if required, for second deck hatch corners should be 2,5 mm greater than the deck thickness.

(b) Inserts will not generally be required for hatch corners on third decks, platform decks and below.

(c) Reinforcement will not generally be required for circular openings, provided that the plate panels in which they are situated are otherwise adequately stiffened against compression and shear buckling.

418 Deck plating forming the upper flange of under-deck girders is to have a thickness, in mm, not less than:—

$$\sqrt{\frac{\text{girder face area (cm}^2\text{)}}{1,8}}$$

and 10 per cent greater than this for hatch side girders. The width of the increased plate is not to be less than 760 mm.

419 For grades of steel in refrigerated ships, see 427.

#### GENERAL

##### Deck Loading

420 For permissible deck loading appropriate to Rule scantlings and for scantlings for specific loading, including concentrated loads but excluding wheeled vehicles, see D 25.

##### Loading by Wheeled Vehicles

421 Where decks are subject to loading from wheeled vehicles, it is recommended that the deck plate thickness should be not less than:—

$$t = 4,6 \sqrt{eW} + 1,5 \text{ mm}$$

where  $W$  = load in tonnes on the tyre print. In assessing  $W$  for fork lift trucks liable to tipping, the total weight of truck and load should be applied to one axle.

$e$  = stress factor obtained from Fig. D 4.5.

Details of tyre pressure, wheel size, wheel load and tyre print dimensions should be supplied by the Shipbuilder. Where this data is not initially available it is suggested that the deck plate thickness be estimated from Table D 4.2.

422 When it is proposed to use vehicles having steel wheels, such as fitted on some pallet trucks, deck thicknesses will be specially considered.

423 If wheeled vehicles are to be used on insulated decks or tank tops, consideration will be given to the permissible loading in association with the insulation arrangements and the plating thickness.

**TABLE D 4.2**  
**APPROXIMATE DECK THICKNESS FOR FORK**  
**LIFT TRUCKS**

CAPACITY OF FORK LIFT tonnes	s/t (max.)
1,0	85
5,0	45
10,0	37
15,0	34
20,0	32

t = plate thickness  
s = actual frame spacing

### Structural Details

424 Attention is to be paid to structural continuity. Abrupt changes of shape or section and sharp corners are to be avoided. The plating at corners of all openings in strength decks is to be well rounded and free from notches. *See also* 409, 412 and 417.

If the deck plating extends inside the coamings within 0,6L amidships, the side coamings are to be extended in the form of tapered brackets.

Where the deck plating stops at the coaming and is welded thereto, through penetration welds are to be used. Where the deck plating extends inside the coaming, the free edges of the plating in way of the hatchways are to be smooth and free of weld attachments.

Arrangements at the welded corners of machinery casings will be considered.

### Sheathed Decks

425 Where plated decks are sheathed with wood or approved composition, the minimum thicknesses given in 403, 405 and 412 may be reduced by 10 per cent for a 50 mm sheathing thickness or 5 per cent for 25,5 mm, with intermediate values in proportion.

The steel deck is to be coated with a suitable material in order to prevent corrosive action, and the sheathing or composition is to be effectively secured to the deck. *See also* F 807 and F 1003.

### Water Testing

426 Weather decks, where riveted, are to be caulked and hose tested on completion.

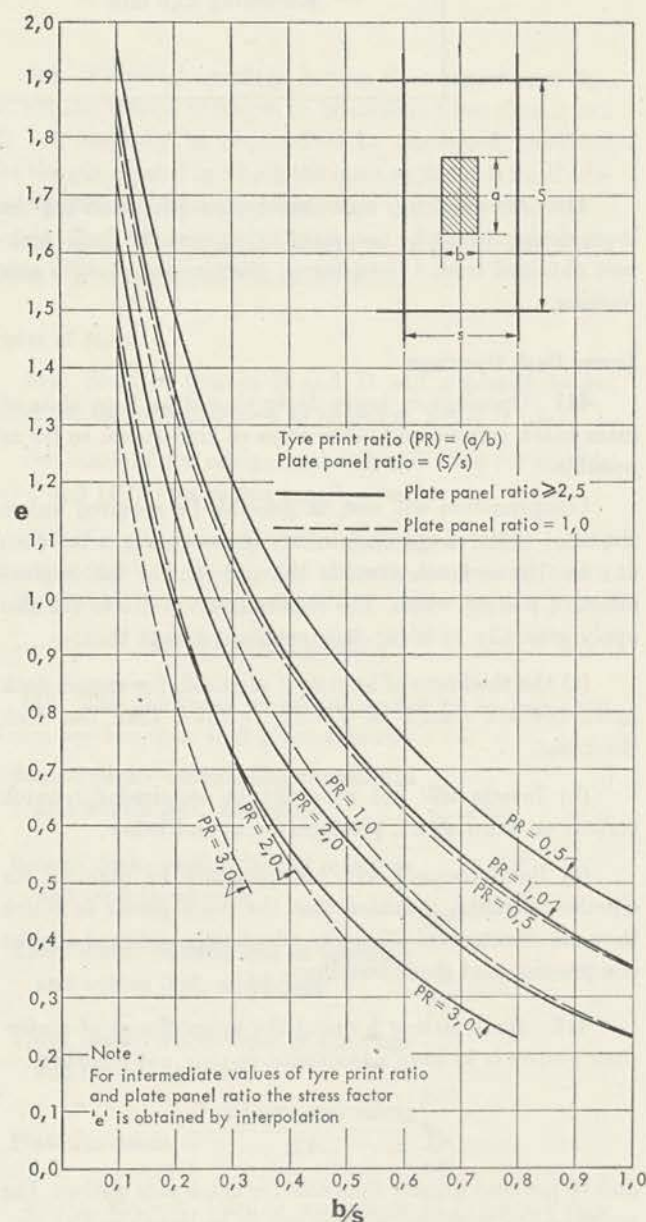
### Refrigerated Ships

427 If the temperature of the steel of the deck can fall to the values given in Table D 4.3, the grade of steel for the following items shall comply with the requirements of the Table:—

Deck plating, webs of deck girders.

Longitudinal bulkhead strakes attached to the deck.

Hatch coaming shelf plates and their face bars.



**FIG. D 4.5 TYRE PRINT LOAD STRESS FACTOR "e"**



TABLE D 4.3

TEMPERATURE DOWN TO	GRADES OF STEEL OR CHARPY V-NOTCH IMPACT TEST REQUIREMENTS FOR STEEL	
	Strength deck within 0,5L amidships	Strength deck at ends second and lower decks
0°C	A (Note 1)	A (Note 1)
-5°C	D (Note 1)	D (Note 1)
-10°C	E	D (Note 1)
-20°C	E	E
-30°C	{ 61J (6,2 kgf m) Minimum average impact energy at the temperature concerned (Note 3)	E (Note 2)
below -30°C		47J (4,8 kgf m) Minimum average impact energy at the temperature concerned (Note 3)

## NOTES

1. Subject to overriding requirements for special steels in other Sections of the Rules.
2. Subject to thickness not exceeding 15 mm. Requirements for greater thicknesses will be subject to special consideration.
3. See Table P 2.2 for minimum average impact energy values for subsidiary Charpy V-notch test pieces.

428 For the purposes of 427, the temperature to which the steel deck may be reduced is to be assessed as follows:—

*Arrangement*

1. Deck not covered with insulation in the refrigerated space.
2. Deck covered with insulation in the refrigerated space and not insulated on the other side.
3. Deck covered with insulation on both sides.

*Deck Temperature*

Temperature of the refrigerated space.

Temperature of the space on the uninsulated side.

(a) Mean of the temperatures of the spaces above and below the deck provided the difference in the temperatures is not more than 11°C.

(b) Mean of the temperatures of the spaces above and below the deck less 3°C if the difference in the temperature is more than 11°C but not more than 33°C.

(c) When the temperature difference is more than 33°C the deck temperature will be specially assessed.

When one of the spaces concerned is not refrigerated, the temperature of that space is to be taken as 5°C.

**Deep Tank**

429 For minimum thickness of plating of a deck forming the crown of tank, see D 1920.

**Mixed Higher Tensile and Mild Steel**

430 When higher tensile steel is used amidships and mild steel at the ends, the taper line for the mild steel is generally to be determined using a nominal mild steel midship thickness of:—

- (a) higher tensile thickness/k if the higher tensile steel thickness is based upon minimum modulus requirements, or
- (b) the minimum mild steel thickness determined from 403, if the higher tensile steel thickness is based upon the minimum thickness requirements.

The higher tensile steel thickness outside the midship 0,4L is to be based upon a taper line from the midship thickness at 0,2L aft or forward of amidships to any point on the mild steel taper line.

Where, however, the arrangement of the deck at ends is such that the width of hatches, etc., differs considerably from that amidships, the tapering may be based on the cross-section areas of the deck plating and associated girders, longitudinals and side shell for a depth of 0,1D such as to avoid any sudden discontinuity of hull modulus at deck.

#### Cross-reference

431 For movable decks, *see* D 35.

### Section 5

#### SHELL PLATING

##### Symbols

- 501  $L$  = length of ship, in metres,  
 $L_1$  = length of ship, in metres, but need not be taken as greater than 190 m,  
 $L_2$  = length of ship, in metres, but need not be taken as greater than 250 m,  
 $D$  = moulded depth, in metres, to the uppermost continuous deck. In way of a superstructure not less than 0,15L in length,  $D$  may be taken to the superstructure deck.  
 $B$  = moulded breadth, in metres,  
 $d$  = moulded draught, in metres,  
 $s$  = spacing of frames or longitudinals, in mm, but is not to be taken less than  $s_b$ ,  
 $s_b$  = standard spacing, in mm, of frames or longitudinals, and is to be taken as:—  
 (a) For 0,05L at ends  
 $s_b = 610$  mm  
 (b) Elsewhere  
 $s_b = 470 + \frac{L_2}{0,6}$  mm  
 but forward of 0,20L from the F.P.,  
 $s_b$  is not to exceed 700 mm,  
 $S$  = distance between stringers or girders, in mm,  
 $R$  = bilge radius, in mm,  
 $t$  = plate thickness, in mm,  
 $M_B$  = actual modulus at keel but is not to be taken greater than 1,5  $M_{B1}$ ,

$M_{B1}$  = Rule modulus at keel from D 3,

$M_D$  = actual deck modulus but is not to be taken greater than 1,5  $M_{D1}$ ,

$M_{D1}$  = Rule deck modulus from D 3,

$$F_B = \frac{M_{B1}}{M_B},$$

$$F_D = \frac{M_{D1}}{M_D},$$

$F_M = F_B$  or  $F_D$ , whichever is the greater,

$k$  = higher tensile steel factor, *see* D 116.

#### General

502 Provision is made for longitudinal or transverse framing for the bottom and side shell, but for ships exceeding 120 m in length, longitudinal framing is, in general, to be adopted at the bottom.

#### Keel

503 The width and thickness of the keel over the whole length are not to be less than the values derived from the following formulæ, nor is the thickness to be less than that of the adjacent shell plating.

Width = 70B mm but need not exceed 1800 mm

$$\text{Thickness} = \left(6 + \frac{L_1}{10}\right) \sqrt{k} \text{ mm}$$

For grades of steel, *see* 511 and 512.

#### Bottom Shell

504 The thickness of bottom shell plating amidships to the upper turn of bilge is to be that necessary to give the section modulus required by D 3, but is not to be less than:—

(a) Longitudinal framing (excluding bilge plating).

$$t = \frac{s}{1000} \left(10 + \frac{L_1}{23}\right) \sqrt{\frac{F_B}{k}} \text{ mm}$$

$$\text{or } t = 0,0063 s \sqrt{\frac{dk}{2 - F_B}} \text{ mm}$$

whichever is the greater.

However, in no case is the thickness to be less than

$$\frac{s}{55\sqrt{k}} \text{ on ships where } L > 190 \text{ m}$$

(b) Transverse framing (excluding bilge plating).

$$t = \frac{s}{1000} \left(1 + \left(\frac{s}{S}\right)^2\right) \left(16,7 + \frac{L_1}{17,8}\right) \sqrt{\frac{F_B}{k}} \text{ mm}$$



$$\text{or } t = 0,0078 s \sqrt{\frac{dk}{2,5 - 1,5 F_B}} \text{ mm}$$

whichever is the greater.

However, in no case is the thickness to be less than

$$\frac{s}{40\sqrt{k}} \text{ on ships where } L > 190 \text{ m}$$

- (c) Bilge plating (longitudinally or transversely framed).

$t$  not less than adjacent bottom plating.

- (d) Bilge plating (unframed).

Provided that transverses or adequate bilge brackets are spaced not further apart than

$$8 \times 10^6 \frac{t^2}{DR} \sqrt{\frac{t}{R}} \text{ mm,}$$

$t = \frac{R}{165k}$ , but is not to be less than that of adjacent bottom plating.

Where intermediate bilge brackets are fitted between transverses on vessels with no bilge longitudinals, then not less than two such brackets should be fitted.

The midship thickness is generally to extend over 0,4L amidships, but the extent may be required to be increased on certain fine, fast ships, and is to be tapered gradually to the end thickness.

Attention is drawn to the fact that shell plating may have to be increased for local strength considerations in way of structure below heavily loaded holds.

For grades of steel, see 511 and 512.

For strengthening of bottom forward, see D 10.

For transversely framed ships, see also 515.

#### Side Shell

**505** The thickness of side shell plating amidships is not to be less than:—

- (a) Longitudinal framing,

the lesser of:

$$t = \frac{s}{1000} \left( 7 + \frac{L}{17} \right) \sqrt{\frac{F_M}{k}} \text{ mm}$$

$$\text{or } t = \frac{s}{55\sqrt{k}} \text{ mm}$$

but not less than

$$0,0049 s \sqrt{dk} \text{ mm above } \frac{D}{2} \text{ from base line, or}$$

$$0,0059 s \sqrt{\frac{dk}{2 - F_B}} \text{ mm at upper turn of bilge.}$$

Intermediate values by interpolation.

- (b) Transverse framing.

- (i) Within  $\frac{D}{4}$  from deck (*but see* 509)

the lesser of:

$$t = \frac{s}{1180 \left( 1 + \left( \frac{s}{S} \right)^2 \right)} \left( 10 + \frac{L}{12} \right) \sqrt{\frac{F_D}{k}} \text{ mm}$$

$$\text{or } t = \frac{s}{46\sqrt{k}} \text{ mm}$$

but not less than

$$0,0049 s \sqrt{dk} \text{ mm}$$

- (ii) Within  $\frac{D}{4}$  of the mid-depth

the lesser of:

$$t = \frac{s}{1000} \left( 7 + \frac{L}{17} \right) \sqrt{\frac{F_M}{k}} \text{ mm}$$

$$\text{or } t = \frac{s}{55\sqrt{k}} \text{ mm}$$

but not less than

$$0,0059 s \sqrt{dk} \text{ mm}$$

- (iii) Within  $\frac{D}{4}$  from bottom (excluding bilge plating)

the lesser of:

$$t = \frac{s}{1180 \left( 1 + \left( \frac{s}{S} \right)^2 \right)} \left( 10 + \frac{L}{12} \right) \sqrt{\frac{F_B}{k}} \text{ mm}$$

$$\text{or } t = \frac{s}{46\sqrt{k}} \text{ mm}$$

but not less than

$$0,007 s \sqrt{\frac{dk}{2,5 - 1,5 F_B}} \text{ mm}$$

nor less than the shell thickness within  $\frac{D}{4}$  of mid-depth.

The midship thickness is generally to extend over 0,4L amidships, but the extent may be required to be increased on certain fine, fast ships, and is to be tapered gradually to the end thickness. The thickness is in no case to be less than that required by 506, but may have to be increased to comply with D 333.

The thickness of side shell need not exceed that determined from 504 (a) or (b) using the spacing of side shell frames or longitudinals.

**End Thickness**

506 The thickness of shell plating for 0,075L from the ends is not to be less than:—

$$t = \left( 6,5 + \frac{L}{30} \right) \sqrt{\frac{s}{s_b}} \text{ mm}$$

**Sheerstrake**

507 The width of sheerstrake amidships is not to be less than 0,1D, and the thickness is not to be less than that of the deck plating or the side shell, whichever is the greater.

Where the side shell is transversely framed up to deck at side, the sheerstrake is also not to be less than the thickness required by the formulæ given in D 403(b).

At ends, the thickness may be the same as the side shell, but provided the draught does not exceed 0,7D (D being measured to the uppermost continuous deck) the end thickness may be as required for a poop or forecastle.

508 The thickness of the sheerstrake is to be increased by 20 per cent at the ends of a bridge, but this increase is not required if the bridge does not extend to the ship's side.

If the poop or the forecastle bulkhead extends within 0,25L from amidships, the sheerstrake at the break is to be increased by 20 per cent.

No increase is required if the poop or forecastle end bulkhead is 0,3L or greater from amidships. The increase at intermediate positions is to be obtained by interpolation and is to be applied to the tapered thickness of the sheerstrake.

509 The upper edge of the sheerstrake is to be dressed smooth and kept free of isolated welded fittings or connections. Bulwarks are not to be welded to the top of the sheerstrake within 0,5L amidships. In ships over 150 m in length, scupper openings are not to be cut above the deck within 0,5L amidships or in way of breaks of superstructures.

510 Where a rounded sheerstrake is adopted, the radius should, in general, not be less than 15 times the thickness. Where Grade E plates are subjected to severe cold working, or where local heating of the plating is adopted, it may be necessary to require re-normalizing of the plate. The welding of fairleads or other fittings to this plate is to be kept to a minimum and details are to be submitted.

**Grades of Steel**

511 In ships between 105 and 135 m in length, the sheerstrake for 0,4L amidships is generally to be Grade B for thicknesses up to and including 20,5 mm and Grade D for thicknesses in excess of 20,5 mm.

Elsewhere, Grade B will generally be required when the thickness is greater than 20,5 mm but does not exceed

25,5 mm, and Grade D will generally be required when the thickness exceeds 25,5 mm as follows:—

- (a) Bottom shell to upper turn of bilge: 0,3L amidships when the length is 155 m and below, and 0,4L amidships when the length is 215 m and above, with intermediate values obtained by interpolation.

Where the bottom plating is required to be of Grade B or D, the keel plate is to be of the same grade.

**(b) Sheerstrake:**

- (i) 0,4L amidships.  
(ii) at the poop front and at the ends of the bridge.  
(iii) outside the limits given in (i), when the thickness exceeds 25,5 mm.

See also D 120 for higher tensile steel.

512 In general, strakes of Grade E steel are to be arranged as follows:—

LENGTH L		GRADE E STRAKES
OVER	NOT EXCEEDING	
metres	metres	
135	170	Sheerstrake ( <i>see</i> Note 1)
170	200	Sheerstrake
200		Sheerstrake
		Bilge strake
		Keel ( <i>see</i> Note 2)

**NOTES**

- In ships between 135 and 170 m in length, the sheerstrake may be Grade D provided the deck plating is also Grade D.
- In ships exceeding 200 m in length, the keel may be Grade D provided the bottom plating is also Grade D.

The Grade E strakes are to extend over 0,4L amidships.

The breadth of each strake is not to be less than 1500 mm, except that the bilge strake shall not be less than 1800 mm and the keel shall be as required by 503.

**Superstructures**

513 The thickness of plating forming the sides of superstructures is to be:—

**1. Outside 0,5L amidships:**

- (a) Forecastle, generally not less than

$$t = \left( 7 + \frac{L}{50} \right) \sqrt{\frac{s}{s_b}} \text{ mm}$$



- (b) Poop, generally not less than

$$t = \left(6 + \frac{L}{60}\right) \sqrt{\frac{s}{s_b}} \text{ mm}$$

2. Within 0,5L amidships:

The thickness of plating forming the sides of superstructures extending within 0,5L amidships will be considered. *See also* D 307.

3. Where bow shape and/or ship speed indicate that unusually high loadings may occur on cargo ships (*see* D 324), or on very large tankers, an increased thickness of plating may be required.

### Openings in Sheerstrake or Shell Plating

514 Cargo door openings are to have well rounded corners. A plan of structure in way of doors indicating proposed compensation is to be submitted for approval.

Sea inlets, or other openings, are to have well rounded corners and, so far as possible, should be kept clear of the bilge radius. Openings on, or near to, the bilge radius should be elliptical. The thickness of sea inlet boxes should be the same as the adjacent shell, but not less than 12,5 mm.

In general, compensation will not be required for holes in the sheerstrake which are clear of any deck openings outside the line of the main hatchways, and whose depth does not exceed 20 per cent of the depth of the sheerstrake or 380 mm, whichever is the lesser.

### Local Stiffening of Bottom Shell

515 In ships with all-welded, transversely framed bottom construction, additional longitudinal stiffeners are to be fitted for 0,4L amidships.

### Local Strengthening

516 The thickness of plates connected to the stern-frame or propeller brackets is not to be less than 50 per cent greater than that required for shell at ends.

Plating in way of hawsepipe is to be suitably increased.

For strengthening for navigation in ice, *see* D 24.

### Bilge Keels

517 Where bilge keels are fitted, it is desirable that they be attached to a continuous flat bar which may be welded to the shell. Scallops are to be arranged at welded butts in the flat bar, or alternatively, a 25,5 mm hole should be drilled in the butt weld just above the fillet weld; in this case, the fillet weld is to be continuous.

Alternative arrangements, or arrangements omitting the flat bar, will be considered.

Bilge keels are to be gradually tapered at their ends and are not to finish on an unstiffened panel.

### Higher Tensile Steel

518 Where higher tensile steel is used amidships and mild steel at the ends, the taper line for the mild steel is to be determined using a nominal mild steel midship thickness of:—

- (a) higher tensile thickness/k or, if the higher tensile steel thickness is based upon minimum thickness requirements:—
- (b) the minimum mild steel thickness determined from 504.

The higher tensile steel thickness, outside the midship 0,4L, is to be based upon a taper line from the midship thickness at 0,2L aft or forward of amidships to any point on the mild steel taper line.

## Section 6

### LONGITUDINAL FRAMING

#### Symbols

- 601 L = length of ship, in metres,  
 $L_1$  = length of ship, in metres, but need not be taken greater than 190 m. *See also* line 6, Table D 6.2,  
d = moulded draught, in metres,  
s = spacing of longitudinals, in mm,  
S = span of longitudinals, in metres, but is not to be taken less than 1,5 m,  
D = moulded depth, in metres, to the uppermost continuous deck,  
H = height from tank top to deck at side amidships, in metres,  
h = vertical distance from side longitudinal to deck at side, in metres,  
 $h_1 = h + 1,6d - D$ , in metres, but need not be taken greater than h.  
In this expression, d is not to be taken less than 0,4D, *see* Table D 6.1, Note 1,  
 $y_1$  = distance from  $\frac{D}{2}$  to tank top, in metres,  
C = nominal stowage rate, in m<sup>3</sup>/tonne, but the value is not to be taken greater than 0,865. "Nominal stowage rate" is the cubic capacity of holds, excluding hatchways, divided by the cargo deadweight or, in specific cases,



is the cubic capacity of a particular hold divided by the weight of cargo stowed therein,

$$F_D = \frac{\text{Rule ship modulus deck}}{\text{actual ship modulus deck}}$$

but is not to be less than 0,83 for use in the following formulæ,

$$F_B = \frac{\text{Rule ship modulus bottom}}{\text{actual ship modulus bottom}}$$

but is not to be less than 0,83 for use in the following formulæ,

$$c_1 = \frac{810}{2450 - 1640 F_D} \text{ at deck,}$$

$$c_2 = \frac{910}{2550 - 1640 F_B} \text{ at keel,}$$

At  $\frac{D}{2}$ ,  $c_1 = c_2 = 1,0$ . Intermediate values by interpolation.

#### Weather Deck Longitudinals, Side Shell Longitudinals, and Bottom Longitudinals

602 The scantlings of longitudinals amidships, are not to be less than required by the following formula:—

$$\frac{I}{y} = 0,0106 s S^2 K_1 \text{ cm}^3$$

where  $K_1$  is taken from Table D 6.1.

The scantlings of longitudinals on weather decks at ends are not to be less than:—

$$\frac{I}{y} = \frac{K_1 s h_3}{100} + \frac{K_2 s}{100} \left( \frac{S L_1}{100} \right)^2 \text{ cm}^3$$

where  $K_1$ ,  $K_2$  and  $h_3$  are taken from Table D 6.2.

For side and bottom longitudinals at ends, see D 10, D 54 and D 55.

603 If the longitudinals carry hanging cargo, such as chilled beef, the modulus determined from 602 is to be increased by 50 per cent if the height of the 'tween deck below is 2,6 m or less, and 100 per cent if the height is 3,2 m (with intermediate heights in proportion) but the modulus need not exceed that derived from 605 for a 2,6 m 'tween deck height above. No increase is required if the modulus derived from 605 is less than that derived from 602.

#### Cargo and Accommodation Decks

604 The section modulus of cargo and accommodation deck longitudinals is not to be less than:—

$$\frac{I}{y} = \frac{K s L_1 + 25 h_4 s S^2}{10\,000} \text{ cm}^3$$

where  $K = 5,9$  for cargo decks,  
 $= 5,1$  for accommodation decks.

$h_4$  = load height, in metres, see D 809.

On accommodation decks, the section modulus need not be taken greater than is given in 602 with  $K_1$  from Table D 6.1, line 1, column 1.

Where wheeled vehicles are to be used on the deck, the section modulus of longitudinals is not to be less than required by D 811, taking  $S$  and  $s$  in the formula as defined in 601, or the value derived above, or by 605 if appropriate, whichever is the greater, and  $T$  as the total wheel load acting on the longitudinal, on vehicles other than fork lift trucks.

For permissible deck loading appropriate to Rule scantlings and for scantlings for specific loadings, see D 25.

605 If cargo deck longitudinals carry hanging cargo such as chilled beef, and may be simultaneously loaded above with cargo, the modulus is to be determined from 604 with  $h_4$  increased by 0,76 m if the height of the 'tween deck below is 2,6 m or less and 2,29 m if the height is 3,8 m (with intermediate heights in proportion). A similar addition is to be made, if appropriate, to accommodation deck longitudinals.

#### Inner Bottom Longitudinals

606 The scantlings of inner bottom longitudinals within the range of cargo holds are not to be less than required by the following:—

(a) In ships of Type 2 (see D 318), the section modulus is not to be less than 85 per cent of the value from Table D 6.1 for bottom longitudinals.

(b) In ships of Type 1 (see D 318) with or without specified holds empty, the following also applies:—

$$\frac{I}{y} = \frac{s S^2 H}{123,6 \left( 1 - 0,233 \frac{y_1}{D} \right) C} \text{ cm}^3$$

If plate girders are fitted alternately with built or rolled sections, the section modulus, as determined above, may be reduced by 10 per cent. The girders are to have a thickness derived from D 927.

#### Webs

607 Webs supporting side longitudinals are, in general, not to be spaced more than 4 m apart when the length,  $L$ , does not exceed 200 m and  $\frac{L}{50}$  for lengths greater than this, and their section modulus is not to be less than:—

$$\frac{I}{y} = 10 s_1 h_2 S_1^2 \text{ cm}^3$$



TABLE D 6.1

LINE NO.	POSITION		$K_1$		
			COL. 1	COL. 2	COL. 3
			TYPE "B"	TYPE "B-60"	TYPE "B-100"
1	Weather deck longitudinals	Outside line of openings	$\frac{22,6L_1}{1780 - L_1} c_1$	$\frac{12,1L_1}{864 - L_1} c_1$	$\frac{L_1}{44} c_1$
2		Inside line of openings abaft of 0,12L from F.P.	$\frac{19,2L_1}{1780 - L_1} c_1$	$\frac{19,2L_1}{1780 - L_1} c_1$	$\frac{L_1}{88} c_1$
3	Side shell longitudinals	Above $\frac{D}{2}$	$\frac{h_1 D}{D + 0,54h} c_1$	$\frac{h_1 D}{D + 0,54h} c_1$	$\frac{hD}{D + 0,54h} c_1$
4		Below $\frac{D}{2}$	$\frac{h_1 D}{1,42D - 0,3h} c_2$	$\frac{h_1 D}{1,42D - 0,3h} c_2$	$\frac{hD}{1,42D - 0,3h} c_2$
5	Bottom longitudinals		$1,11 d c_2$	$1,11 d c_2$	$1,11 d c_2$

## NOTES

1. TYPE "B":  $h_1$  not to be less than  $\frac{22,6L_1}{1780 - L_1}$   
 TYPE "B60":  $h_1$  not to be less than  $\frac{12,1L_1}{864 - L_1}$   
 TYPE "B-100":  $h$  not to be less than  $\frac{L_1}{44}$
2.  $d$  is generally not to be taken less than  $0,6D$  and need not be taken greater than  $0,8D$ .
3. Tapering of deck longitudinals is allowed outside  $0,4L$  amidships, to values as given from Table D 6.2, lines 1 and 2.
4. The section modulus of side longitudinals in topside wing tanks is to be that determined as for side shell longitudinals, but is not to be less than required for the sloping bulkhead. See 610.
5. Where a W.T. longitudinal bulkhead (or a wing tank bulkhead) is fitted adjacent to the side shell, the modulus of side longitudinals need not be taken greater than that derived from line 5, using  $c_2$ -value at keel.
6. If a strut is fitted at approximately half-span, the modulus of bottom longitudinals may be reduced by 50 per cent. For requirements of struts, see D 918, where  $Z$  is to be taken as the modulus of the bottom longitudinal as determined from line 5. Parallel allowances are to be made to side and deck longitudinals when a double side shell or double deck is provided.
7. In way of the brackets required by D 926, the span,  $S$ , used in determining the required modulus of longitudinals may be the spacing of the brackets, or  $1,25$  m, whichever is the greater.

where  $S_1$  = spacing of webs, in metres,

$h_2$  = distance, in metres, from mid-point of span to upper deck at side amidships,

$S_1$  = span of web, in metres.

Where topside tanks are fitted or in ships of Type 1 (see D 318), the strength of these webs may require to be increased. In general, the standard of strength is not to be less than that required by D 715.

For arrangements in machinery spaces at aft end, see D 55.

For arrangements in fore and aft peaks, see D 54 and D 55.

### Bilge Longitudinals

608 The scantlings of bilge longitudinals are to be graduated between those required for the bottom longitudinals and the lowest side longitudinal.

Where no bilge longitudinal is fitted, two bilge brackets attached to the longitudinals at the upper and lower turns of bilge may be required to be fitted between transverses.

### Hopper Side Tanks

609 If longitudinals are fitted to the sloping tank top forming a hopper side tank, their section modulus is not to be less than required by 606.  $H$  may, in this case, be measured vertically from the centre of the sloping portion to the intersection with the sloping plating of the topside tank, or to the deck at side if no topside tank is fitted.

### Topside Wing Tank

610 Longitudinals on the sloping bulkhead of topside tanks are to have a section modulus not less than:—

$$\frac{I}{y} = \frac{H_1 s S^2}{100} \text{ cm}^3$$

TABLE D 6.2

LINE	LOCATION OF WEATHER DECK LONGITUDINAL	$K_1$	$K_2$	$h_3$ metres
1	At 0,12L from F.P. outside line of openings	4,85	0,62	1,2+2,04E but not less than 1,2 nor greater than 1,5 (See Note 2)
2	At and abaft 0,1L from A.P.	4,00	0,50	
3	Between 0,12L and 0,075L from F.P. outside and inside line of openings	5,70	0,72	1,5
4	Forward of 0,075L from F.P. outside and inside line of openings	6,35	0,78	1,8
5	Bridge where forming an effective superstructure	6,75	0,72	
6	Short bridge or poop ( $L_1$ for short bridge or poop need not be taken as greater than 153 m)	4,65	0,50	0,9+2,04E but not less than 0,9 nor greater than 1,2

### NOTES

1. 
$$E = \frac{0,0914 + 0,003L}{D - d} - 0,15$$

2. For decks above the uppermost continuous deck,  $h_3$  obtained from the formula for lines 1 and 2 can be successively reduced by 0,31 m for each deck to a minimum of 0,45 m.



where  $H_1$  is the greater of the following heads, in metres:—

- (a) measured from the outboard longitudinal to the gunwale or outboard corner of the tank,
- (b) two-thirds of the distance, measured parallel to the plating, from the outboard longitudinal to the inboard corner of the tank.

Where a plate diaphragm is fitted, the longitudinals inboard of this may be determined using  $H_1$  equal to the perpendicular distance between the sloping bulkhead and the gunwale or outboard corner of the tank.

#### General

**611** The unsupported span of bottom longitudinals is generally not to exceed 2,5 m and is to be measured as indicated in Fig. D 1.3.

The thickness of flat bar longitudinals continuous at bulkheads is not to be less than one-eighteenth of the depth. Where not continuous, the thickness should not be less than one-fifteenth of the depth.

Longitudinals of the flat bar type are not to be scalloped, but isolated drain or air holes may be provided.

Flat bar longitudinals (if cut from plate) and through brackets to longitudinals, on deck, bottom and side shell for 0,1D from deck and bottom, are to be of the following grades of steel for 0,4L amidships:—

Grade B where thickness exceeds 20,5 mm  
but does not exceed 25,5 mm,

Grade D where thickness exceeds 25,5 mm.

Built longitudinals are to comply with the requirements of D 4008 and D 4404. For higher tensile steel, see D 120.

**612** Where L exceeds 215 m, the bottom and deck longitudinals should be continuous through the transverse bulkheads, but alternative arrangements will be considered.

**613** End connections of longitudinals to bulkheads are to provide adequate fixity and, so far as practicable, direct continuity of longitudinal strength.

**614** End connections of longitudinals are generally to be in accordance with D 16.

#### Section 7

##### TRANSVERSE SIDE FRAMING

#### Symbols

- 701** L = length of ship, in metres,  
D = moulded depth, in metres,

$D_1$  = D but need not be taken as greater than 1,6d,

$D_2$  = D but need not be taken as greater than 1,6d or 16 m whichever is the lesser,

d = moulded draught, in metres,

s = frame spacing, in mm,

H = (a) Main frames—vertical framing depth, in metres, measured at side as indicated in Figs. D 7.1 and D 7.2.

(b) 'Tween deck frames—vertical 'tween deck height, in metres, measured at side. In way of sheer, H is to be measured, in general, at the middle of the length of each compartment. Where sheer is excessive, H will be specially considered.

Values of H in (a) and (b) are not to be less than 2,5 m.

$K = 1 - \frac{x}{5q}$  but not less than 0,35,

x = distance, in metres, measured as shown in Fig. D 7.2,

q = minimum height of double bottom, in metres, as determined from D 904,

f = factor, obtained from Fig. D 7.3.

#### General

**702** All scantlings for main frames are based on Rule welded end connections. If brackets differing from Rule size are fitted, the modulus of the frame is to be corrected—see 726.

**703** The minimum inertia for all frames is given in 724.

#### Frame Spacing

**704** The frame spacing between 0,2L from forward and the after peak bulkhead is not, in general, to exceed 1000 mm.

**705** The frame spacing between 0,2L from forward and the fore peak bulkhead is not, in general, to exceed

700 mm where  $D_1$  is greater than 8,9 m and

$\frac{1000D_1}{24} + 330$  mm where  $D_1$  is less than 8,9 m.

**706** The frame spacing in peaks and cruiser sterns is not, in general, to exceed 610 mm.

**Main and 'Tween Deck Frames**

**707** The section modulus of main and 'tween deck frames is not to be less than given below (*see also* 719):

between 0,2L aft of the forward perpendicular and the after peak bulkhead,

$$\frac{I}{y} = \frac{Pds}{760} \text{ cm}^3 \quad (1)$$

between 0,2L aft of the forward perpendicular and the line of the fore peak bulkhead,

$$\frac{I}{y} = \frac{Pdsf}{700} \text{ cm}^3 \quad (2)$$

'tween deck frames aft of the line of the after peak bulkhead and forward of the line of the fore peak bulkhead,

$$\frac{I}{y} = \frac{Pdsf}{610} \text{ cm}^3 \quad (3)$$

In (1), (2) and (3) above, P depends on where the lower end of the frame is connected as follows:—

To a hopper side tank, or to a double bottom  
 $\geq$  Rule height,

$$P = (1,35H^2 + 0,11KD_1^2 + 11) \left(1 - \frac{x}{1,4D}\right) \quad (4)$$

Where, due to the shape of the ship towards the ends, the rigidity of the hopper side tank is reduced, the modulus of the main frame may require to be increased.

To a deck or flat ('tween deck frame—*see also* 709),

$$P = (1,35H^2 + 0,11D_1^2 + 11) \left(1 - \frac{x}{1,4D}\right) \quad (5)$$

**708** Where spans forward of 0,2L from the fore perpendicular are in excess of 9 m, intercostal stringers are to be fitted in line with alternate peak stringers.

**709** The minimum section modulus of a 'tween deck frame is not to be less than:—

$$\frac{I}{y} = \frac{D_1s}{110} \text{ cm}^3$$

**710** At positions where there are more than four decks, the modulus in 707 may be reduced and the minimum modulus of the 'tween deck frames will be specially considered.

**711** The four frames nearest the end of a superstructure which terminates within 0,25L amidships are to

extend from the 'tween decks below to the superstructure deck. Equivalent arrangements are to be made when the ship's side is framed longitudinally.

**712** All 'tween deck and superstructure frames are to be efficiently scarfed to the main frames below or effectively attached to the deck. For end connections and welding, *see* D 16.

**Peak Frames**

**713** The frames in the fore and aft peaks are to extend as indicated in Fig. D 7.3, and are to have a section modulus not less than:—

$$\frac{I}{y} = 2,8 d D_2 \text{ cm}^3$$

This modulus applies in conjunction with Rule side stringers spaced vertically 2,0 m apart in the fore peak tank, and 2,5 m in the after peak tank (*see* D 11) and with a 'tween deck height of 2,6 m above the peak tanks, measured vertically.

Where the spacing of the stringers exceeds 2,0 or 2,5 m, the modulus of the frames is to be increased in direct proportion.

Where the 'tween deck height above the peak tanks exceeds 2,6 m, or where curvature or slope is very great, intermediate stringers may be required.

**714** Web frames are to be arranged in the 'tween decks above the after peak tank at every fourth frame abaft the after peak bulkhead, and are to have a section modulus not less than that required by D 5512.

**Web Frames, or Frames of Increased Scantlings, in Cargo Holds**

**715** Where topside tanks are fitted, vertical web frames may be fitted in line with the topside tank transverses (*see also* D 1919), and are to have a section modulus not less than:—

$$\frac{I}{y} = \left(\frac{I}{y}\right)_f + \frac{I s_1 H^2 h}{26,7} \text{ cm}^3$$

where

$\left(\frac{I}{y}\right)_f$  = section modulus of main frame in  $\text{cm}^3$  obtained from 707,

H is as defined in 701,

l = length of hold, in metres, but is not to be taken less than 20 m and need not be taken greater than 25 m,



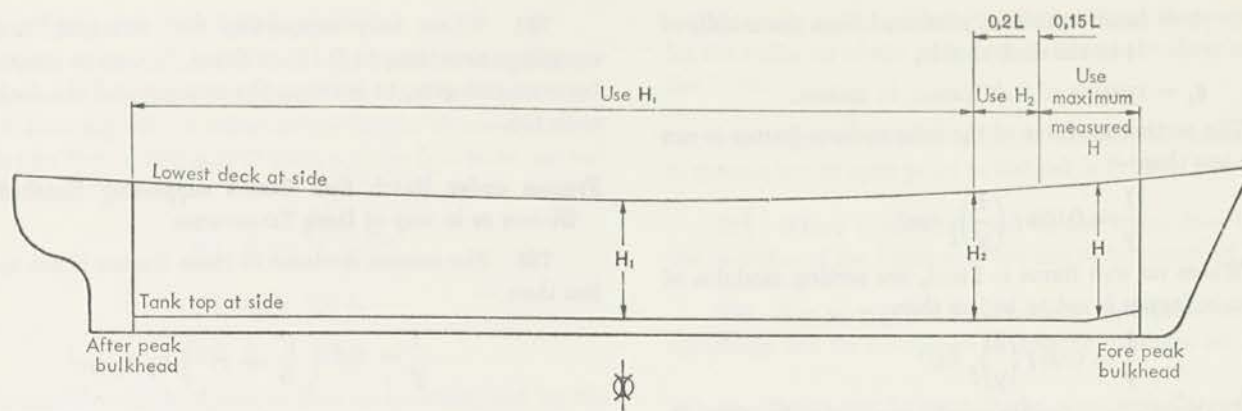


FIG. D 7.1 MEASUREMENT OF H FOR MAIN FRAMES ALLOWING FOR SHEAR

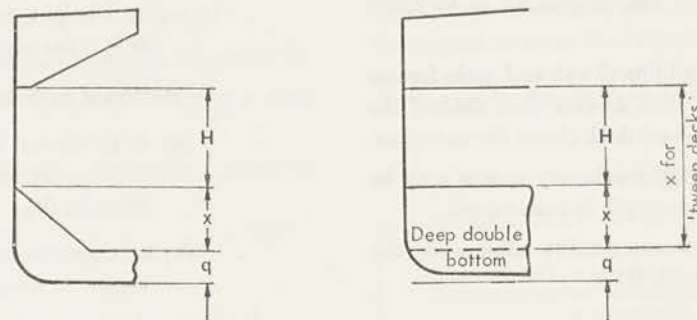
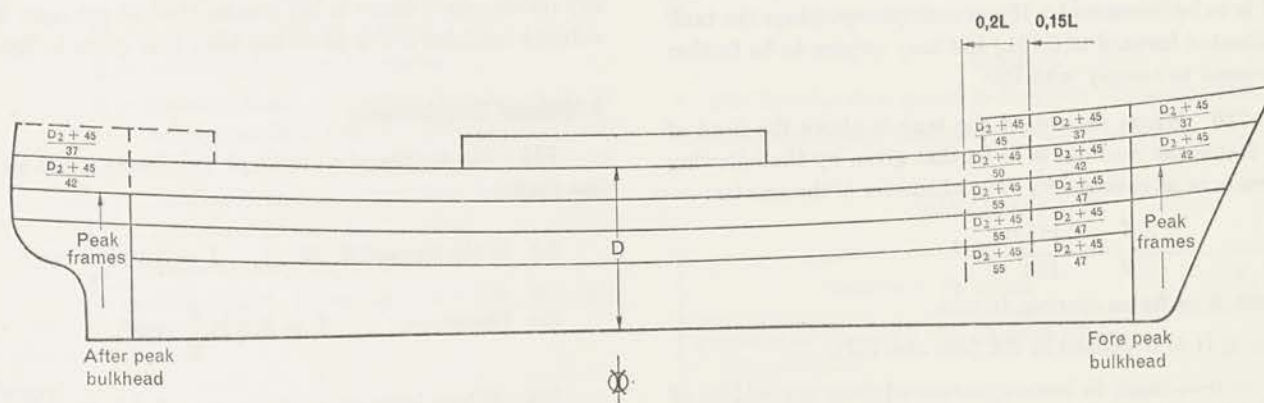
FIG. D 7.2 MEASUREMENT OF H, x AND q WHERE A HOPPER SIDE TANK OR DEEP DOUBLE BOTTOM IS FITTED  
(FOR 'TWEEN DECKS x IS TO BE MEASURED EXCLUDING SHEER)

FIG. D 7.3 SHOWING DISTRIBUTION OF FACTOR f.

$h$  = head, in metres, measured from the middle of  $H$  to the deck at side,

$s_1$  = spacing of web frames, in metres.

The section modulus of the intermediate frames is not to be less than:—

$$\frac{I}{y} = 0,036 l \left( \frac{I}{y} \right)_f \text{ cm}^3$$

Where no web frame is fitted, the section modulus of the main frames is not to be less than:—

$$\frac{I}{y} = 0,05 l \left( \frac{I}{y} \right)_f \text{ cm}^3$$

The webs of web frames may be required to be stiffened.

716 End connections are to be in accordance with D 16.

#### Frames in Engine and Boiler Room

717 Vertical web frames are, in general, to be fitted in the engine room.

The combined section modulus of web and main frames is to be not less than 50 per cent greater than that of the Rule main frames up to the lowest deck above the waterline.

The web frames in midship machinery spaces may be omitted provided the overall strength is maintained.

Where machinery spaces are at the after end, the arrangements are to comply with D 55.

#### Side Framing in way of Tanks, and Cargo Holds used for Water Ballast

718 Paragraphs 719 to 721 apply to oil fuel bunkers, settling tanks, deep tanks and cargo holds used for water ballast or cargo oil.

719 The section modulus derived in accordance with 707 is to be increased by 15 per cent (except where the tank is situated forward of 0,15L) but may require to be further increased to comply with 720.

720 Where the top of the tank is above the head of the frame the modulus is to be that given by the following formula or as required by 719, whichever is the greater:—

$$\frac{I}{y} = \frac{s H^2 h}{150} \text{ cm}^3$$

where  $s$  = frame spacing, in mm,

$H$  is as defined in 701 (See also 721),

$h$  = head, in metres, measured from the middle of  $H$  to the deck at side or half the head from the middle of  $H$  to the top of the overflow, whichever is the greater.

721 Where fully supporting side stringers, having scantlings according to D 19 are fitted,  $H$  may be measured between stringers, or between the stringer and the deck or tank top.

#### Frames under Hatch End Beams supporting Hatch Side Girders or in way of Deck Transverses

722 The section modulus of these frames is not to be less than:—

$$\frac{I}{y} = 2,5 \left( \frac{l^2}{5} + H^2 \right) h_t S_t \text{ cm}^3$$

where  $l$  = distance, in metres, from side shell to inboard support of beam or transverse,

$H$  = vertical framing depth or 'tween deck height of frame concerned, as defined in 701 but need not be taken greater than 3,5 m,

$h_t$  = load height, in metres, as given in D 6 and D 8. (See also D 1306, D 1321 and D 25),

$S_t$  is defined as follows:—

(a) at hatch end beams  $S_t$  = length of hatch, in metres, divided by 4, but not less than that given in (b),

(b) at transverses  $S_t$  = actual spacing of transverses, in metres.

In no case is the modulus to be less than that required for the normal side frame.

723 Where the modulus required for frames under deck transverses exceeds that obtained from 707 and 719 to 721, the intermediate frames may be reduced provided the combined modulus is maintained and the reduction in any intermediate frame is not greater than 35 per cent. The reduced modulus is not to be less than that given in 709.

#### Additional Requirements

724 The inertia of a frame or web frame is not to be less than:—

$$(a) \text{ In the forward } 0,15L, \quad I = 3,5 H \frac{I}{y} \text{ cm}^4$$

$$(b) \text{ Elsewhere, } \quad I = 3,2 H \frac{I}{y} \text{ cm}^4$$

725 Where holes are drilled or punched in the inboard flange of frames, the size of the frame may require to be increased in order to maintain the required section modulus in way of the holes.



**Beam Knees and Tank Side Brackets**

726 Beam knees and tank side brackets are generally to have scantlings in accordance with D 16. Where, however, it is proposed to adopt actual lengths of arm  $a_1$  and  $b_1$  different from  $a$  and  $b$  in D 1605, a value  $l_a$  is to be derived such that:—

$$(a) \quad l_a = \frac{a_1 + b_1}{2}$$

$$(b) \quad a_1 \geq 0,8 l_a$$

$$(c) \quad b_1 \geq 0,8 l_a$$

The modulus of the frame is then to be multiplied by the following factor:—

$$\text{where } l_a > l, \quad \text{factor} = 1,1 - 0,1 \frac{l_a}{l}$$

$$\text{where } l_a \leq l, \quad \text{factor} = 1,2 - 0,2 \frac{l_a}{l}$$

**Cross-references**

727 For strengthening for navigation in ice, see D 24.

For side frames in conjunction with cantilever deck supports, see D 15.

Where an approved system of corrosion control is provided, see D 2.

**Section 8****DECK BEAMS****Symbols**

- 801  $L$  = length of ship, in metres,  
 $B$  = moulded breadth, in metres, but need not be taken greater than 21,5 m,  
 $D$  = moulded depth, in metres,  
 $d$  = moulded draught, in metres,  
 $S$  = Span of beam, in metres, but is not to be taken less than 1,83 m. Forward of 0,075L aft of the fore perpendicular the span of forecastle and weather deck beams is not to exceed 3,7 m. See also 803.  
 $s$  = beam spacing, in mm,  
 $h$  = load height, in metres. See 806, 809 and D 25.

**General**

802 Beams are to be fitted at every frame.

Beams at the crown of deep tanks, peak tanks and oil fuel tanks are to satisfy the requirements of this Section

but are not to be less in strength standard than that required for the stiffeners of the boundary bulkheads to those tanks. See D 19.

803 Span to be used in the formulæ is to be measured, in metres, to the span point as defined in D 130.

804 Where there are holes in the beam face flange the modulus of the beam may require to be increased.

805 For permissible deck loading appropriate to Rule scantlings and for scantlings for specific loadings, see D 25.

**Weather Decks and Strength Decks other than Cargo Decks**

806 The section modulus of weather deck beams and strength deck beams is not to be less than:—

$$\frac{I}{y} = \frac{K_1 K_2 d D}{1000} + \frac{K_3 h B S^2 s}{10\,000} \text{ cm}^3$$

but the modulus need not exceed twice the value given by the second term in the formula.

$K_1$ ,  $K_2$  and  $K_3$  are given in Tables D 8.1, D 8.2 and D 8.3:—

**TABLE D 8.1**

NUMBER OF DECKS AT THE POSITION OF THE BEAM UNDER CONSIDERATION, INCLUDING SUPERSTRUCTURE DECKS, BUT EXCLUDING FORECASTLES	$K_1$
1	20,0
2	13,3
3	10,5
4 or more	9,3

**NOTES**

1. The  $K_1$  value for a forecastle deck may be taken as 13,3.
2. A sloping topside tank may be counted as a deck.

**TABLE D 8.2**

LOCATION OF BEAM	$K_2$
Forward of a point 0,12L aft of the fore perpendicular	80,0
Short bridges and poops	13,3
Elsewhere	53,0

TABLE D 8.3

LOCATION OF BEAM	$K_3$
Beam span adjacent to ship's side	3,6
Forward of a point 0,075L abaft the fore perpendicular, on forecastles and weather decks	5,4
Elsewhere	3,3

Aft of 0,12L from the fore perpendicular:—

$h = 1,2 + 2,04E$  metres, and is not to be less than 1,2 m nor greater than 1,5 m.

$$\text{where } E = \frac{0,0914 + 0,003L}{D - d} - 0,15$$

Between 0,075L and 0,12L from forward,  $h$  is 1,5 m. In the forward 0,075L, including forecastle decks,  $h$  is 1,8 m. For decks above the uppermost continuous deck,  $h$  obtained from the above formulæ can be successively reduced by 0,310 m for each deck, to a minimum of 0,450 m.

807 If the beams carry hanging cargo, such as chilled beef, the modulus determined from 806 is to be increased by 50 per cent if the height of the 'tween deck below is 2,6 m or less and 100 per cent if the height is 3,2 m (with intermediate heights in proportion), but the modulus need not exceed that derived from 810 for a 2,6 m 'tween deck height above. No increase is required if the modulus derived from 810 is less than that derived from 806.

#### Carriage of Timber on Weather Decks

808 Where timber load lines are to be assigned, see D 25.

#### Cargo and Accommodation Decks

809 The section modulus of cargo and accommodation deck beams is not to be less than:—

$$\frac{I}{y} = \frac{K_1 K_4 d D}{1000} + \frac{3,88 h S^2 s}{1000} \text{ cm}^3$$

$K_1$  is a constant obtained from Table D 8.1 and  $K_4$  is given in Table D 8.4.

For cargo decks  $h$  is the mean height of the 'tween deck in metres. Where insulation is fitted underneath a deck, the 'tween deck height may be reduced by 150 mm.

For decks under accommodation spaces  $h$  is 1,2 m. For decks above the uppermost continuous deck this value

TABLE D 8.4

TYPE OF DECK	$K_4$
Cargo	40
Accommodation	53

can be successively reduced by 0,31 m for each deck to a minimum of 0,45 m.

Decks under ship store spaces other than refrigerated stores can, in general, be based on  $h$  equal to 2,0 m. For engine room stores or flats  $h$  is 2,6 m.

810 If cargo deck beams carry hanging cargo such as chilled beef and may be simultaneously loaded above with cargo, the modulus is to be determined from 809 with  $h$  increased by 0,76 m if the height of the 'tween deck below is 2,6 m or less and 2,29 m if the height is 3,8 m (with intermediate heights in proportion). A similar addition is to be made, if appropriate, to accommodation deck beams.

#### Wheeled Vehicles

811 Where wheeled vehicles are to be used, the section modulus of the beams is not to be less than:—

$$\frac{I}{y} = \frac{375 K_5 TS}{K_7} + \frac{1,25 K_6 h S^2 s}{1000} \text{ cm}^3$$

or that derived from 809 or 810 if appropriate, whichever is the greater,

where  $K_5$ ,  $K_6$  and  $K_7$  are coefficients obtained from Table D 8.5,

$T$  = total weight of a fork lift truck and its load, or the greatest axle load of other wheeled vehicles, in tonnes.

#### Beam Knees and their Attachments

812 The scantlings of beam knees and their welded attachment are to be in accordance with D 16 and Table D 32.3 respectively.

813 In ships having more than three tiers of beams and where large areas of deck are arranged for accommodation, or where particular conditions of loading are contemplated, the requirements for beam knees will be considered.

814 The attachment of half beams to hatch side coamings and casings is given in Table D 32.1.



TABLE D 8.5

WHEEL SPACING* BEAM SPAN	K <sub>5</sub>	K <sub>6</sub>
0,1	15,40	1,890
0,2	14,60	1,845
0,3	13,35	1,730
0,4	11,80	1,550
0,5 and greater	10,10	1,300

K<sub>7</sub> = 1000 for fork lift trucks.

K<sub>7</sub> = 700 for permanent vehicle decks on ferries, in association with h which need not exceed 2,5 m.

K<sub>7</sub> = 270 for portable car decks on ferries in association with h = 0.

\* Outer wheel to outer wheel on axles with multiple wheel arrangements.

#### Cross-references

815 For strong hatch end beams and deck transverses, see D 13.

For strengthening in machinery spaces, see D 21.

For cantilevers, see D 15.

### Section 9

#### DOUBLE BOTTOMS

##### Symbols

- 901 L = length of ship, in metres,  
 B = moulded breadth, in metres,  
 d = moulded draught, in metres,  
 s = spacing of frames or longitudinals, in mm,  
 D<sub>DB</sub> = minimum depth of centre girder, in mm, see 904,  
 k = higher tensile steel factor, see D 116.

##### Application

902 This Section provides for longitudinal or transverse framing in the double bottom, but for ships exceeding 120 m in length, longitudinal framing is, in general, to be adopted. Longitudinal framing is to be adopted for ships of Type 1 (see D 318).

903 Where specified cargo holds may be empty in the loaded condition, see 941 to 949.

##### Centre Girder

904 The depth of the centre girder is not to be less than given by:—

$$D_{DB} = \frac{1000B}{36} + 205 \sqrt{d} \text{ mm}$$

The thickness is not to be less than:—

$$t = 0,008D_{DB} + 4 \text{ mm for 0,4L amidships}$$

$$\text{and } t = 0,008D_{DB} + 2 \text{ mm for 0,1L at ends}$$

For duct keels, see 931.

##### Inner Bottom Plating

905 The thickness of the inner bottom plating in the holds is not to be less than:—

$$t = 0,00136(s + 660) \sqrt[4]{LD} \text{ mm for 0,4L amidships (1)} \\ \text{nor less than}$$

$$t = 0,00127(s + 660) \sqrt[4]{LD} \text{ mm for 0,1L at ends (2)}$$

For ships of Type 1 (see D 318), the thickness derived from the above is to be increased by 5 mm but is not to be less than:—

$$t = \frac{s\sqrt{W}}{690} \text{ mm} \quad \left( t = \frac{s\sqrt{W}}{220} \text{ mm} \right) \quad (3)$$

W = tank top loading, in kN/m<sup>2</sup> (tonne-f/m<sup>2</sup>), and calculated as:—

$$\frac{\text{Weight of cargo in hold, tonnes}}{\text{Volume of hold, m}^3} \times \frac{\text{Head from tank top to deck line at centre, m}}{\text{tonne-f/m}^2} \times 9,81 \text{ kN/m}^2$$

$$\left( \frac{\text{Weight of cargo in hold, tonnes}}{\text{Volume of hold, m}^3} \times \frac{\text{Head from tank top to deck line at centre, m}}{\text{tonne-f/m}^2} \right)$$

For ships of Type 2 (see D 318), the thickness of the inner bottom plating as determined above is to be increased by 2 mm under the hatchways if no ceiling is fitted, (see D 227).

For recommendations for thickness of plating when wheeled vehicles are to be used, see D 421 to D 423.

906 Where the double bottom tanks are common with wing ballast tanks or cofferdams, the thickness of the inner bottom plating is to be not less than required by D 1920 for the crown of a tank.

907 If cargo is to be regularly discharged by grabs, it is recommended that double ceiling be fitted or the thickness of the plating be not less than 5 mm thicker than that required by 905, formula (1) or (2), and fitted with a flush surface.

#### Margin Plate

908 A margin plate, if fitted, is to have a thickness throughout 20 per cent greater than required for inner bottom plating amidships. See 905.

909 In passenger ships, the inner bottom plating is to be continued out to the ship's side in such a manner as to protect the bottom to the turn of bilge. Such protection will be satisfactory if the line of intersection of the outer edge of the margin plate with the bilge plating is not lower at any part than a horizontal plane passing through the point of intersection with the frame line amidships of a transverse diagonal line inclined at 25 degrees to the base line and cutting it at a point one-half the ship's moulded breadth from the middle line.

### TRANSVERSE FRAMING

#### Plate Floors

910 Plate floors are to be fitted at every frame in the engine room and forward as required by D 10. They are also to be fitted under the boiler bearers, bulkheads, foes of brackets to deep tank bulkhead stiffeners and in way of any change in depth of double bottom. Partial plate floors are to be fitted under the thrust seating. Floors of increased thickness are to be arranged in way of shaft brackets.

911 In ships from which cargo is to be regularly discharged by grabs, it is recommended that plate floors be fitted at every frame.

912 Except as required by 910, plate floors may be spaced not more than 3,05 m apart, and the shell and inner bottom plating between these floors is to be supported by bracket floors.

913 The thickness of non-watertight plate floors is not to be less than:—

$$t = 0,008D_{DB} + 1 \text{ mm}$$

but need not exceed 15 mm.

914 Watertight or strengthened floors are to be fitted below, or in the vicinity of, watertight bulkheads, and their thickness is to be 2 mm greater than given in 913 for non-watertight floors, but need not exceed 15 mm on floors of normal depth.

D 907 - D 918

If the depth of such floors exceeds 915 mm but does not exceed 2000 mm, the floors are to be fitted with vertical stiffeners spaced not more than 915 mm and having a section modulus not less than:—

$$\frac{I}{y} = \frac{D_{DB_1}^2 \times h_{DB} \times s_{DB}}{185 \times 10^6} \text{ cm}^3$$

where  $D_{DB_1}$  = actual depth of floor, in mm,

$h_{DB}$  = head from top of inner bottom to top of overflow pipe, in metres,

$s_{DB}$  = stiffener spacing, in mm.

The ends of the stiffeners are to be sniped.

915 Where the double bottom tanks are common with wing ballast tanks or cofferdams, or where the depth of floor exceeds 2000 mm, the scantlings of watertight floors are to be not less than required by D 19 for a tank bulkhead, and the ends of the stiffeners are to be bracketed top and bottom. When floors form the boundary of a sea inlet box, the thickness of the plating is to be as required by D 514, and the stiffening (which should all be situated outside the box where practicable) is to be not less than that required by D 19 for tank bulkheads.

#### Bracket Floors

916 The bottom frames are to have a section modulus not less than:—

$$\frac{I}{y} = 215S_1sd \times 10^{-4} \text{ cm}^3$$

where  $S_1$  is unsupported span, in metres.

The reversed frames are to have a section modulus not less than 85 per cent of that given above for the bottom frames and the unsupported span of bottom and reversed frames is not to exceed 2,5 m.

917 The breadth of the brackets attaching the frames and the reversed frames to the centre girder and margin plate is to be three-quarters of the depth of the centre girder; the brackets are to be flanged on the unsupported edge and are to have the same thickness as the plate floors.

918 Where struts are fitted to reduce the unsupported span of the frames and reversed frames they are to have a cross-sectional area not less than:—

$$A = 0,32 Z \text{ cm}^2 \text{ for } Z \leq 83,5$$

$$A = 23,2 + \frac{Z}{25} \text{ cm}^2 \text{ for } Z > 83,5$$

where  $Z = \frac{I}{y}$  of bottom frame determined from 916.



**Side Girders**

919 One side girder is to be fitted when the breadth,  $B$ , does not exceed 20 m, and for greater breadths two girders are to be fitted on each side of the centreline. The girders are to extend as far forward and aft as practicable and are to have a thickness not less than:—

$$t = 0,008D_{DB} + 1 \text{ mm}$$

Vertical stiffeners are to be fitted at every bracket floor and are to have a depth not less than the depth of the reversed frame, or 150 mm, whichever is the greater. The thickness is to be as required for the girder.

For side girders in the forward  $0,3L$ , see D 10.

Watertight side girders are to have a thickness 1 mm greater than given above.

920 In the machinery space and thrust recess, the number and disposition of the side girders are to be such as to support the machinery effectively and to secure the necessary rigidity of structure.

**LONGITUDINAL FRAMING**

921 Where longitudinal framing is adopted in the double bottom (see 902) the scantlings of the longitudinals are to be determined from D 602, D 606 and D 608. Plate girders are to have a thickness determined from 927.

**Plate Floors**

922 Plate floors are to be fitted at every frame under the main engines and the foremost shaft tunnel bearing and at alternate frames outboard of the engine seating. They are also to be fitted under boiler bearers, bulkheads and the toes of brackets of deep tank bulkhead stiffeners.

Elsewhere, the spacing of the floors is not to exceed 3,7 m in ships of Type 2, or 2,5 m in ships of Type 1 (see D 318 for definitions of ship types).

For spacing of floors in the forward  $0,3L$ , see D 10.

923 The thickness of plate floors is not to be less than:—

$$t = 0,009D_{DB} + 1 \text{ mm}$$

The thickness need not be greater than 15 mm but the ratio between the depth of the double bottom and the thickness of floor is not to exceed 130. This ratio may, however, be exceeded if suitable additional stiffening is fitted.

924 Vertical stiffeners are to be fitted at each longitudinal, having a depth not less than 150 mm and a thickness equal to the thickness of the floors.

925 For watertight floors the plate thickness is not to be less than the greater of the thicknesses determined from 914 and 923. The section modulus of the stiffeners is not to be less than required by D 1908 with  $\omega_1$  and  $\omega_2$  taken equal to 1,0 and  $e_1$  and  $e_2$  equal to 0, or as required by 924, whichever is the greater. The stiffeners are to be connected to the inner bottom and bottom longitudinals.

926 Between plate floors, transverse brackets having a thickness not less than  $0,009D_{DB}$  mm are to be fitted extending from the centre girder and margin plate to the adjacent longitudinal. The brackets, which are to be suitably stiffened at the edge, are to be fitted at every frame at the margin plate and those at the centre girder are to be spaced not more than 1,25 m.

For duct keels, see 931.

**Side Girders**

927 One side girder is to be fitted where the breadth,  $B$ , exceeds 14 m and two girders are to be fitted on each side of the centreline where  $B$  exceeds 21 m. In ships of Type 1 (see D 318), the spacing of side girders is not to exceed 3,7 m.

The girders are to extend as far forward and aft as practicable and are to have a thickness not less than:—

$$t = 0,0075D_{DB} + 1 \text{ mm}$$

Watertight side girders are to have a thickness 1 mm greater than given above and stiffeners are to be in accordance with 914.

For side girders in the forward  $0,3L$ , see D 10.

928 The longitudinal girders under the main machinery are to extend for the full length of the machinery space and are to be carried aft to support the foremost shaft tunnel bearing. This extension abaft the after engine room bulkhead is to be at least three transverse frame spaces. Forward of the engine room the girders are to be tapered off over three transverse frame spaces and are to be efficiently scarfed into the longitudinal framing system.

929 A vertical stiffener is to be arranged midway between floors when these are spaced more than two frame spaces apart. The stiffeners are to have a depth not less than 100 mm and a thickness equal to the girder thickness.

930 Where, at the ends of the ship, the longitudinal system of framing is replaced by a transverse system, adequate arrangements are to be made to avoid abrupt discontinuities.



## GENERAL

**Duct Keels**

931 Where duct keels are arranged, the side plates are to have a thickness not less than 1 mm greater than required by 919. The sides are, in general, not to be spaced more than 1,83 m apart. The inner bottom and bottom shell within the duct keel are to be suitably stiffened, and continuity of floors is to be maintained.

**Increased Thicknesses in Engine Rooms**

932 In engine rooms the thickness of the inner bottom plating is not to be less than:—

$$t = 0,0015 (s + 660) \sqrt[4]{Ld} \text{ mm}$$

**Manholes and Lightening Holes**

933 Sufficient holes are to be cut in the inner bottom floors and side girders, to provide adequate ventilation and access to all parts of the double bottom. The edges of all holes are to be smooth. The size of opening should not, in general, exceed 50 per cent of the double bottom depth, unless edge reinforcement is provided. In way of ends of floors and fore and aft girders at transverse bulkheads, the number and size of holes is to be kept to a minimum, and the openings are to be circular or elliptical. Edge stiffening may be required in these positions. The requirements of 946 and 948 regarding area of floor and girder are also to be complied with where applicable.

934 Where manhole covers are attached by bolts to the inner bottom plating, doubling rings are to be fitted to take the fastenings of the covers. Manhole covers which project above the inner bottom plating are to be adequately protected.

**Ships Loading and Discharging Aground**

935 It is recommended that the bottoms of ships intended to load or discharge aground be additionally strengthened in order to withstand the stresses to which they may be subjected.

**Longitudinal Subdivision**

936 If oil fuel is to be carried in double bottoms, holes are not to be cut in the centre girder except in the forward and after tanks, and elsewhere where tanks are narrow due to subdivision. When timber load lines are to be assigned, double bottom tanks within the midship half-length are to have adequate longitudinal subdivision.

The centre girder need not be tested.

**Pumping and Drainage**

937 The arrangements are to be in accordance with the requirements of Chapter E. Provision is to be made for the free passage of air and water from all parts of the tanks to the air pipes and suction, taking into account the pumping rates required.

**Testing**

938 Each compartment is to be tested on completion with a head of water representing the maximum pressure which could be experienced in service. Alternatively, air testing in accordance with D 5202, excluding the structural test, may be carried out.

It should be noted that this air test applies only to double bottoms and combined double bottom and lower hopper side tanks, provided they are not connected to topside tanks.

When double bottom tanks and lower hopper tanks are connected to topside tanks, then testing is to be in accordance with D 1934.

**Higher Tensile Steel**

939 Where higher tensile steel is used, the height of the double bottom is to be as required by the appropriate Sections of the Rules, but the thickness of floors, girders and tank top are to be multiplied by the factor  $\sqrt{k}$ , see D 116.

The factor is to be applied to the Rule thickness of tank top plating, and the full increase for grab discharge (if applicable) added to this corrected thickness.

**Cross-references**

940 For additional stiffening under heels of pillars, see D 1408.

For strengthening of bottom forward, see D 10.

For compartments carrying oil fuel or lubricating oil, see D 1927 and D 1932.

For reserve feed water compartments, see E 710.

**CARRIAGE OF HEAVY CARGOES  
WITH SPECIFIED OR ALTERNATE HOLDS EMPTY**

941 Where in ships of Type 1 (see D 318), a notation permitting specified or alternate holds to be empty is to be assigned, the following requirements are to be complied with. Alternatively, the scantlings may be assessed by direct calculation using an agreed procedure.



## Symbols

942  $w$  = double bottom loading, in  $\text{kN/m}^2$  (tonne-f/m<sup>2</sup>), and is to be taken as:—

$W-6,67d$  ( $W-0,68d$ ) for full holds, and  
 $10d$  ( $1,02d$ ) for empty holds,  
 where  $W$  is as defined in 905,

$b$  = span of floors, in metres, measured to inter-section of hopper side or ship's side, and tank top,

$l$  = length of hold, in metres, measured between bulkhead stools, where fitted, at the level of the tank top on the centreline,

$S_1$  = spacing of floors, in metres,

$S_2$  = half the distance between girders adjacent to the girder in question, in metres,

$\alpha = \frac{l}{b}$  and is not to be taken as less than 0,5 nor greater than 1,5.

$\alpha_c = 1,15 - 0,275k_1$

$k_1 = \frac{p^3}{p^3 + 305q^2\alpha}$

Where there is no hopper side tank,  $k_1$  is to be taken as zero and if the slope of the hopper side is less than 30° to the horizontal the value of  $k_1$  will be considered.

$k_2 = k_1(0,205 - 0,024\alpha) + 0,312\alpha + 0,034$   
 when  $0,5 < \alpha \leq 1,0$

or  $k_1(0,349 - 0,168\alpha) + 0,168\alpha + 0,178$   
 when  $1,0 < \alpha \leq 1,5$

$k_3 = 0,192\alpha + 0,148 - k_1(0,192\alpha - 0,092)$   
 when  $0,5 < \alpha \leq 1,0$

or  $0,04\alpha + 0,30 - k_1(0,04\alpha + 0,06)$   
 when  $1,0 < \alpha \leq 1,5$

$p$  = girth of hopper side tank, including hopper side and double bottom height, in metres,

$q$  = depth of double bottom, in metres. Where the tank top slopes from the side to the centreline,  $q$  is to be taken as the least depth plus three-quarters of the rise.

NOTE.  $q$  may be taken initially as derived from 904. Where this height of double bottom is increased to comply with 943 or 944 successive calculations will be required.

$t$  = thickness of inner bottom plating (see 905 and 906) or bottom shell plating, whichever is the least, in mm. Where high tensile steel is fitted the equivalent mild steel thickness is to be used.

The proportion of the double bottom load carried by the transverse bulkhead is:—

$$\frac{k_3}{k_2 \frac{l}{b} + k_3}$$

The actual value of  $\frac{l}{b}$  should be used ignoring the upper and lower limits in the definition of  $\alpha$ .

943 The depth of centre girder is not to be less than required by 904 or the following, whichever is the greater:—

$$\frac{cwb^2P}{9,81t} \text{ mm} \quad \left( \frac{cwb^2P}{t} \text{ mm} \right)$$

where  $P = 0,054\alpha - k_1(0,0349\alpha - 0,0134) - \frac{\delta}{100}$

$c = 89$  } when  $\alpha \geq \alpha_c$   
 $\delta = 0$  }

$c = 114,5$  } when  
 $\delta = 5,55k_1(\alpha - 0,6)^2 + 5,63(\alpha - 0,7)^2(1 - k_1)$  }  $\alpha < \alpha_c$

944 The depth of double bottom is to be such that the depth of floor at the hopper side tank is not less than:—

$$\frac{9,07wb^2k_1}{t} \left( \frac{0,0892\alpha^3}{0,283 + \alpha^3} \right) \text{ mm}$$

$$\left( \frac{89wb^2k_1}{t} \left( \frac{0,0892\alpha^3}{0,283 + \alpha^3} \right) \text{ mm} \right)$$

945 When the depth of the hopper side tank derived from 944 exceeds that required by 943 the inner bottom plating may be sloped, but the height at the centreline is not to be less than required by 904 or 943. Alternatively, the double bottom may have the height required by 904 or 943 and the thickness of the inner bottom plating or bottom shell (or both) is to be increased in way of the hopper side tank so that the requirement of 944, using the increased thickness, is satisfied. The increased thickness is to extend 610 mm outboard of the hopper side knuckle and  $\frac{b}{10}$  metres inboard of the knuckle and over the length of the hold concerned.

946 Plate floors are to be spaced not more than 2,5 m and are to have a thickness giving a net sectional area (excluding openings) at the hopper side of:—

$$0,0907S_1wbk_2 \text{ cm}^2 \quad (0,89S_1wbk_2 \text{ cm}^2)$$

for the middle half-length of the hold.

$$0,0647S_1wbk_2 \text{ cm}^2 \quad (0,635S_1wbk_2 \text{ cm}^2)$$

for the quarter-length of the hold at each end.

The net sectional area (excluding openings) at any point  $y$  metres from the centreline, is not to be less than  $2y/b$  times the required area at the hopper side. The thickness is not to be less than required by 923.

**947** If intermediate partial floors extending from the hopper side tank to the next plate longitudinal are fitted, they are to have a thickness not less than  $0,009D_{DB}$  mm and 75 per cent of their thickness may be taken into account in assessing the area of floors required by 946.

**948** Plate girders are to be spaced not more than:—

$$1,4 + \frac{L_1}{180} \text{ m}$$

where  $L_1$  = length of ship, in metres, but not to be taken as greater than 215 m.

They are to have a thickness giving a net sectional area (excluding openings) at the bulkheads of:—

$$0,0907S_2wbk_3 \text{ cm}^2 \quad (0,89S_2wbk_3 \text{ cm}^2)$$

for the middle half-breadth of the hold,

$$0,0647S_2wbk_3 \text{ cm}^2 \quad (0,635S_2wbk_3 \text{ cm}^2)$$

for the quarter-breadth of the hold at each side.

The net sectional area (excluding openings) at any point  $x$  metres forward or aft of the mid-length of the hold is not to be less than  $\frac{2x}{l}$  times the required area at the bulkheads. The thickness is not to be less than required by 927.

**949** If intermediate partial plate girders extending from the bulkhead to the next plate floor are fitted, they are to have a thickness not less than  $0,009D_{DB}$  mm and 75 per cent of their thickness may be taken into account in assessing the area of girders required by 948.

## Section 10

### STRENGTHENING OF BOTTOM FORWARD

#### Symbols

**1001**  $L_1$  = length of ship, in metres, but need not exceed 215 m,

$C_b$  = block coefficient at load draught,

$s$  = frame or longitudinal spacing, in mm,

$s_b$  = standard frame spacing in mm, i.e.

- (a) forward of  $0,2L$  from fore perpendicular:—  
as required by D 705 and D 706,

(b) aft of  $0,2L$  from fore perpendicular:—

$$\frac{L_1}{0,6} + 510 \text{ mm}$$

#### Extent

**1002** The bottom forward is to be strengthened for the following extent except when the ship is so designed that a ballast draught forward of  $0,04L_1$  can be achieved:—

$C_b$  of 0,70 or under — between  $0,05L$  and  $0,3L$  from forward

$C_b$  of 0,80 or over — between  $0,05L$  and  $0,25L$  from forward

At intermediate  $C_b$ , the extent may be obtained by interpolation.

#### Bottom Framed Longitudinally

**1003** (a) Longitudinal spacing is to be in accordance with D 704 and D 705.

(b) Plate floors are to be fitted on alternate frames and are to have scantlings not less than required by D 923.

(c) Bottom longitudinals are to have scantlings in accordance with D 602 using a minimum span of 1,85 m.

(d) Side girders are to be fitted not more than 2,1 m apart and are to have scantlings required by D 927.

#### Bottom Framed Transversely

**1004** (a) Frames are to be spaced in accordance with D 704, D 705 and D 706.

(b) Plate floors are to be fitted at every frame and are to have scantlings not less than required by D 913.

(c) Side girders are to be fitted not more than 2,2 m apart and are to have scantlings required by D 919.

(d) Half-height side girders are to be fitted not more than 1,1 m apart and are to have scantlings not less than required by D 919. They are to extend as far forward as practicable.

#### Shell Plating

**1005** Where the ship is so designed that a ballast draught forward of  $0,04L_1$  can be achieved, no increase in the thickness of shell plating is required.



Where the ballast draught forward is  $0,03L_1$  or less, the thickness of the strakes wholly or partly covering the flat of bottom within the region defined in 1002 is not to be less than:—

$$t = 0,092L_1 + 7\sqrt{\frac{s}{s_b}} \text{ mm}$$

For intermediate draughts the thickness is to be obtained by interpolation between the above value and the tapered thickness. For this purpose, the nominal thickness at  $0,2L$  from amidships for a ballast draught of  $0,04L_1$  may be taken as that required by D 504 (a) or (b) as appropriate, using the minimum spacing of

$$\frac{L_1}{0,6} + 510 \text{ mm}$$

If the spacing differs from that given in 1001 the tapered thickness is to be corrected in the ratio  $\sqrt{\frac{s}{s_b}}$ .

The midship thickness of the strakes referred to above is to be carried forward to the increased plating.

The thickness of the keel plate is not to be less than that of the adjoining plating.

**1006** If intermediate stiffening is fitted, the thickness of the bottom shell plating may be 80 per cent of that required by 1005 but is not to be less than the normal taper thickness.

#### General

**1007** Floors and girders are to be connected to the shell by continuous welding, and drain holes are to be kept to a minimum.

### Section 11

#### PANTING

##### Symbols

**1101**  $L$  = length of ship, in metres,

$L_1$  = length of ship, in metres, but need not be taken greater than 215 m,

$B_1$  = moulded breadth, in metres, but need not be taken greater than 32 m,

$l$  = vertical spacing, in metres, of stringers and panting beams,

$h$  = vertical distance, in metres, from the stringers to the line of the deck at side amidships,

$s$  = horizontal spacing of beams, in metres,

$S$  = span of beams, in metres, measured from the flange of the stringer, or from half the distance between the edge of the stringer and the inboard side of the framing when the stringer is unflanged, to the centreline support, or to the opposite span point where no centreline support is provided.

#### General

**1102** The structure is to be strengthened to resist panting for  $0,15L$  from the fore end, and abaft the after peak bulkhead.

#### Forward of the Collision Bulkhead

**1103** Tiers of beams to be spaced not more than 2 m apart vertically are to be fitted to alternate frames in the fore peak tank, or below the lowest deck above the waterline if the peak tank is small, and are each to have a cross-sectional area not less than:—

$$A = 2,5B_1 - \frac{L_1}{25} \text{ cm}^2$$

In addition, the least moment of inertia of any beam is not to be less than:—

$$I = lhsS^2 \text{ cm}^4$$

Alternatively, perforated flats may be fitted in lieu of panting beams. The arrangement and scantlings of these flats are to be as required by D 5417 and D 5439 (1).

**1104** In general, the tiers of beams are to be supported at the centreline by a partial wash bulkhead or pillars.

**1105** The beams are to be connected to the side frames by brackets having a depth below the stringer, measured along the inboard side of the frame, not less than

$$\frac{150A}{t} \text{ mm}$$

where  $A$  = sectional area of beam, in  $\text{cm}^2$ , obtained from 1103,

$t$  = thickness of bracket, in mm, and is to be not less than the thickness of stringer plate (see 1106).

In no case is the cross-sectional area through the throat of the bracket to be less than  $A$ .

Frames to which a beam is not fitted are to be attached to the stringer plate by brackets having the same thickness as the stringer (see 1106) and having a depth measured at the shell of half the width of the stringer plate.

1106 Stringer plates attached to the shell are to be fitted at each tier of beams, and are to have scantlings not less than:—

$$\text{Width} = 3,3L + 400 \text{ mm}$$

$$\text{Thickness} = \frac{2,5L}{100} + 6 \text{ mm}$$

#### Abaft the Collision Bulkhead

1107 Intercoastal side stringers having the same depth as the frames, a face flat of width  $L$  mm and the thickness required by 1106, are to be fitted in line with those forward of the collision bulkhead and are to extend aft for the distance defined in 1102; they are to be attached to the shell by welding having a weld factor of 0,35. See Notes to Table D 32.1.

The stringers may be omitted provided that the shell plating is increased by 15 per cent for vessels having a length up to and including 150 m, and 5 per cent where the length is 215 m and above. For intermediate lengths, the percentage may be obtained by interpolation.

For hold frames having spans in excess of 9 m, see D 708.

1108 Tank side brackets are to be fitted to all frames and the strength of the attachment of the frames to the tank side brackets is to be increased by 20 per cent above the requirements of D 16.

#### Abaft the After Peak Bulkhead

1109 The structure is to be efficiently stiffened by deep floors and tiers of beams in association with stringers, having scantlings required by 1103 and 1106 respectively, except that they may be spaced 2,5 m apart vertically.

In twin screw ships, the frames abaft the propeller brackets and up to the lowest deck are to be attached to the shell plating by welding having a weld factor of 0,44. See Notes to Table D 32.1.

Special arrangements may be required in single screw ships of high speed.

If, on account of the ship's form, the unsupported length of frames exceeds 2,5 m, additional stiffening may be required.

For details of welding in after peak structure, see Table D 32.1 and D 5521.

#### Deep 'Tween Decks

1110 In ships having deep 'tween decks, additional intercoastal side stringers may be required or the thickness of the shell plating is to be suitably increased.

#### Cross-references

1111 For framing and webs in peaks, see D 713 and D 714.

For structure in bulbous bows, see D 5441.

#### Section 12

#### STEMS AND STERNFRAMES

##### Symbols

1201  $L$  = length of ship, in metres,

$L_1$  = length of ship, in metres, but need not be taken as greater than 215 m,

$d$  = moulded draught, in metres,

$V$  = maximum service speed, in knots, with the ship in the loaded condition.

##### Materials

1202 Steel castings are to comply with the requirements of P 5.

1203 Forgings are to comply with the requirements of P 6.

#### STEMS

1204 Bar stems are to have scantlings not less than:—

$$A = 1,6L - 32 \text{ cm}^2$$

where  $A$  = cross-sectional area of the stem bar, in  $\text{cm}^2$ .

Above the load waterline the dimensions may be gradually tapered to the stem head where the area may be reduced by 25 per cent.

1205 Where the stem is constructed of shaped plates, the thickness of the plates below the load waterline is to be not less than:—

$$t = 0,083L_1 + 5 \text{ mm}$$

where  $t$  = thickness of plating, in mm.

Above the load waterline the thickness may be gradually tapered to the stem head, where it may have the same thickness as the shell at ends, see D 506.

1206 Plate stems are to be supported by horizontal webs between the decks and below the lowest deck; the unsupported length of stem plates is not to exceed 1,5 m.



Where the curvature of the plate is large, a centreline web may be required.

For strengthening of plate stems for navigation in ice, see D 24.

For bulbous bows, see D 54.

### STERNFRAMES

**1207** Sternframes may be cast or forged or may be fabricated from plate.

Cast steel and fabricated sternframes are to be strengthened at intervals by transverse webs. In castings, sudden changes of section or possible constrictions to the flow of metal during casting are to be avoided. All fillets are to have adequate radii which should not, in general, be less than 50 to 75 mm depending upon the size of the casting.

**1208** All sternframes are to be efficiently attached to the ship structure and the lower part of the sternframe is to be extended forward to provide an efficient connection to the flat plate keel.

#### Propeller Posts

**1209** The scantlings of propeller posts are to be not less than shown in Figs. D 12.1 and D 12.2 for the appropriate type of construction.

##### (a) Fabricated propeller post

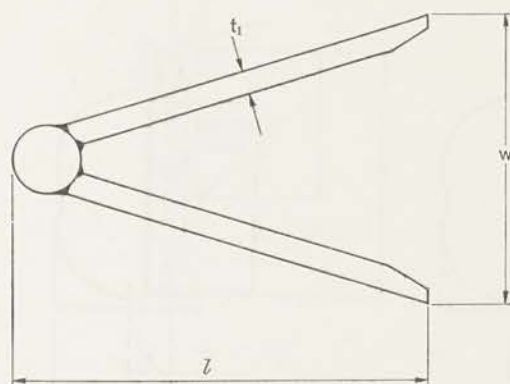


FIG. D 12.1

$$l = 200 \sqrt{d} \text{ mm}$$

$$w = 140 \sqrt{d} \text{ mm}$$

$$t_1 = 12 \sqrt{d} \text{ mm}$$

##### (b) Cast propeller post

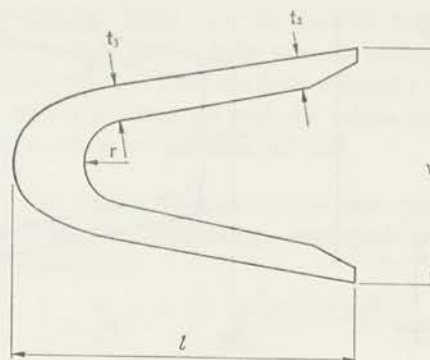


FIG. D 12.2

$$l = 165 \sqrt{d} \text{ mm}$$

$$w = 115 \sqrt{d} \text{ mm}$$

$$t_2 = 12 \sqrt{d} \text{ mm (minimum 19 mm)}$$

$$t_3 = 16 \sqrt{d} \text{ mm (minimum 25,5 mm)}$$

$$r = 20 \sqrt{d} \text{ mm}$$

In cast propeller posts, the thickness of transverse webs is not to be less than  $0,65t_2$  but need not exceed 38 mm.

#### Connection

**1210** Rudder posts are to be connected to a transom floor of the same depth as that required for a double bottom floor and having a thickness 2,5 mm greater than that required by D 913.

#### Stern Frames on Twin Screw Ships

**1211** The dimensions of rudder posts which are built integral with the hull of twin screw ships are not to be less than shown in Fig. D 12.3.

#### Solepiece

**1212** (a) The minimum section modulus,  $\frac{I}{y_t}$ , of a cast steel solepiece against transverse bending at any point in the solepiece at a distance  $x$  metres from the centreline of the rudder pintles or their equivalent, is not to be less than:—

$$\frac{I}{y_t} = \frac{400Ac (V + 3)^2 (3x + a)}{b (L + 640)} \text{ cm}^3$$

where  $a$ ,  $b$ ,  $c$  and  $x$ , in metres, are as shown in Figs. D 12.4 (a), D 12.4 (b) and D 12.4 (c) and  $A$  = total area of rudder in  $\text{m}^2$ .

(b) For a fabricated solepiece the minimum transverse section modulus may be taken as  $0,85 \frac{I}{y_t}$ .

D 1207 - D 1212

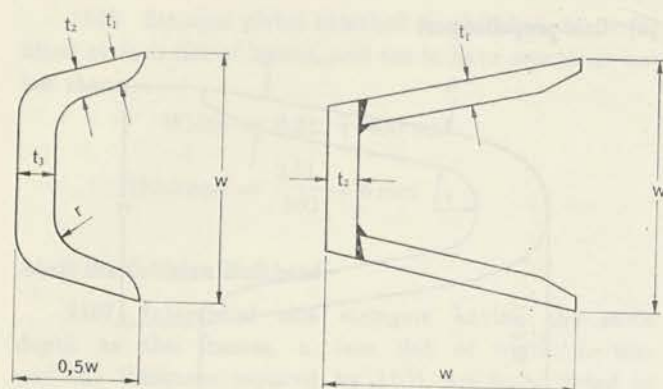


Fig. D 12.3

$$w = 120 \sqrt{d} \text{ mm}$$

$$t_1 = 12 \sqrt{d} \text{ mm}$$

$$t_2 = 15 \sqrt{d} \text{ mm}$$

$$t_3 = 18 \sqrt{d} \text{ mm}$$

$$r = 20 \sqrt{d} \text{ mm}$$

(c) Where the solepiece is connected to the upper part of the sternframe by a bolted axle, the section modulus in (a) or (b) above may be reduced by 5 per cent. Where an integral rudder post is fitted having scantlings in accordance with 1216, the section modulus in (a) or (b) above may be reduced by 50 per cent.

**1213** The minimum section modulus against vertical bending is not to be less than  $0,50 \frac{I}{y_t}$  if the sternframe is open, not less than  $0,40 \frac{I}{y_t}$  if a bolted rudder post is fitted, and not less than  $0,35 \frac{I}{y_t}$  if an integral rudder post is fitted.

**1214** In fabricated solepieces, transverse webs are to be fitted not more than 760 mm apart; they need not be attached to the top plate.

A centreline vertical web is to be fitted where the breadth of the solepiece exceeds 900 mm.

#### Propeller Boss

**1215** The finished thickness of the propeller boss is not to be less than  $0,1d_s + 56$  mm, where  $d_s$  is the shaft diameter, in mm.

#### Rudder Post

**1216** Rudder posts supported at their lower end by a solepiece are to have a section modulus against transverse bending not less than:—

$$\frac{I}{y} = \frac{Ab(V+3)^2}{6,8} \text{ cm}^3$$

where A and b are as defined in 1212.

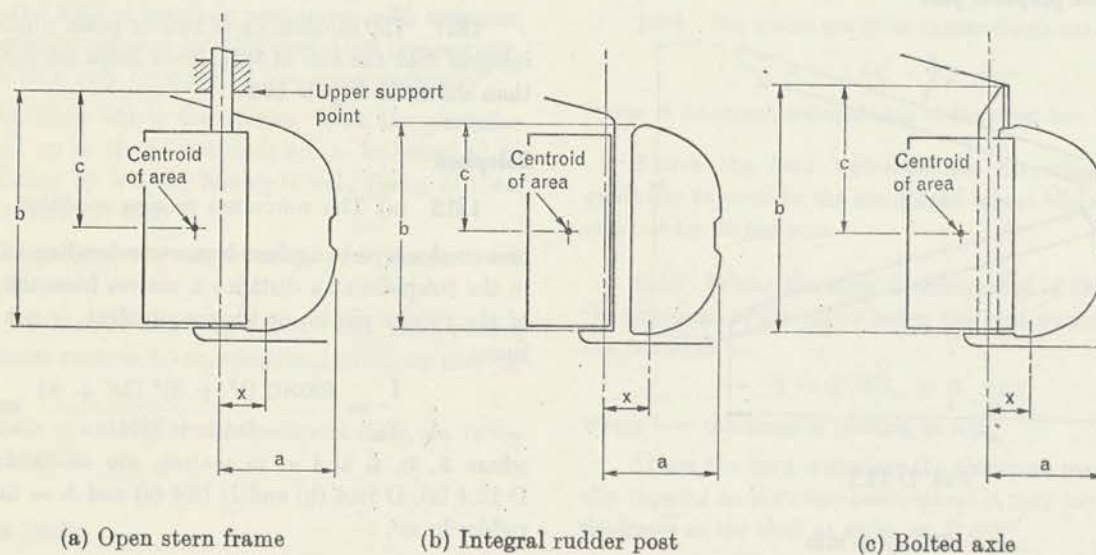


Fig. D 12.4



**Rudder Axle**

**1217** The design of the axle is to be such as to avoid sudden changes of section.

The diameter of an axle for a balanced type rudder is not to be less than  $25d + 76$  mm but need not exceed 90 per cent of  $D_2$ . The diameters  $D_1$  and  $D_2$  are not to be less than required by D 2209 for rudder pintles and the lengths  $l_1$  and  $l_2$  are not to be less than  $1,2 D_1$  and  $1,2 D_2$  respectively (see Fig. D 12.5). The bearing pressure is to be in accordance with D 2210.

**1218** The axle is to be connected to the hull by 6 bolts in a palm flange as shown in Fig. D 12.5. The diameter of the bolts and palm thickness is not to be less than:—

$$6,25d + 19 \text{ mm or } 7 + 0,94 \sqrt{A_p} \text{ mm}$$

whichever is the greater, where  $A_p$  is as defined in D 2209.

The mean distance of the bolt centres from the centre of the palm face is not to be less than the Rule axle diameter in 1217. If more than 6 bolts are fitted, the arrangements are to provide equivalent strength.

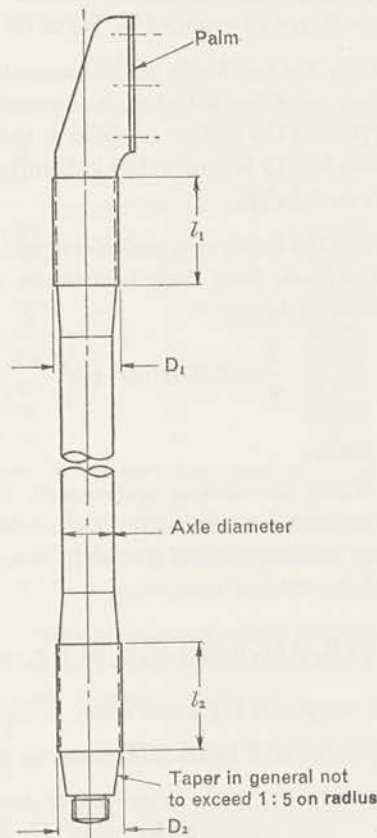


FIG. D 12.5

**Rudder Horn**

**1219** Rudder horns may be cast or fabricated; if fabricated, Grade D steel is to be used for plates exceeding 25,5 mm in thickness. They are to be efficiently integrated into the main hull structure and the radius at the shell connection is not to be less than 305 mm.

**1220** The section modulus against transverse bending of a rudder horn when supporting a semi-spade type rudder is not to be less than:—

$$\frac{I}{y} = \frac{A (V + 3)^2 \sqrt{h^2 + 0,5g^2}}{530} \text{ cm}^3$$

where  $A$  = total area of rudder, in  $\text{m}^2$ ,  $h$  and  $g$  are in mm. See Fig. D 12.6.

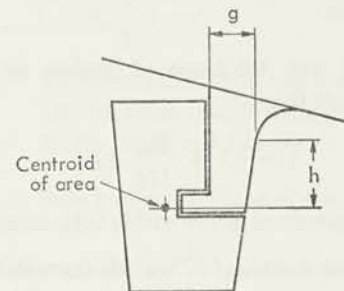


FIG. D 12.6

**Propeller Clearances**

**1221** For recommended minimum propeller clearances for single and twin screw ships, see Chapter R (G).

**Ice Strengthening**

**1222** For strengthening for navigation in ice, see D 24.

**Section 13****DECK GIRDERS AND TRANSVERSES****Symbols**

**1301**  $b$  = mean width, in metres, of deck (or deck and hatchway where applicable) supported by the girder or transverse,

$d_w$  = depth of web, in mm,

$F$  =  $\frac{\text{Rule midship section modulus}}{\text{actual midship section modulus}}$ ,

$h$  = load height, in metres, as given in D 6 and D 8 (see also 1306, 1321 and D 25),

$k$  = higher tensile steel factor, see D116,

$S$  = span of girder or transverses, in metres between points of support. If an end bracket is fitted the span may be taken to a point which is half the distance between the toe of the end bracket and the support point.

#### General

1302 For the forward 0,075L of forecastle and weather decks, longitudinal girders supporting beams are not to be spaced more than 3,7 m apart, and transverses supporting deck longitudinals are not to be spaced more than 2,5 m apart. Elsewhere, transverses supporting deck longitudinals are to be spaced not more than 4,0 m apart when the length does not exceed 200 m and  $\frac{L}{50}$  for lengths greater than this.

1303 The web thickness of girders or transverses should not be less than:—

$$t = 6,5 + \frac{d_w}{170} \text{ mm}$$

but when a longitudinal girder within 0,4L amidships on the strength deck has a ratio of  $\frac{d_w}{t} > 55$ , the web may require to be stiffened or increased in thickness.

For moment of inertia requirement, see 1312.

1304 The section modulus of deck and bottom girders, except as covered by D 2516, is to be multiplied by the factor  $k$ , and the spacing of longitudinal stiffeners on the web is not to be greater than  $55t \sqrt{\frac{k}{F}}$ , but in no case is to exceed  $65t \sqrt{k}$  for 0,4L amidships.

#### Longitudinal Girders and Transverses supporting Deck Longitudinals

1305 The section modulus for longitudinal girders or transverses supporting deck longitudinals is not to be less than:—

$$\frac{I}{y} = 4,75 b h S^2 \text{ cm}^3$$

In single deck ships the section modulus of the transverses is to be increased by 15 per cent.

1306 On weather decks forward of 0,075L from the fore perpendicular, the section modulus of longitudinal girders and transverses supporting deck longitudinals is to be based on the above formula, using the  $h$  for weather deck amidships increased by 3 m and the depth of the girder or

transverse is not to be less than twice that of the beam or longitudinal supported.

#### Weather Deck Hatch Side Girders (including Coamings)

1307 The section modulus for weather deck hatch side girders supporting transverse beams or deck transverses is not to be less than that required by (a) or (b) below.

- (a) When the hatch side girder supports one, two or three point loads (taking a stowage rate of 1,39 m<sup>3</sup>/tonne the section modulus is to be based on a stress of 101 N/mm<sup>2</sup> (1025 kgf/cm<sup>2</sup>) assuming 100 per cent end fixity,
- (b) When the hatch side girder supports four or more point loads from deck transverses, or an evenly distributed load:—

$$\frac{I}{y} = 5,85 b h S^2 \text{ cm}^3$$

#### 'Tween Deck Hatch Side Girders

1308 The section modulus of 'tween deck hatch side girders supporting transverse beams or deck transverses is not to be less than that required by (a) or (b) below.

- (a) When the hatch side girder supports one, two or three point loads (taking a stowage rate of 1,39 m<sup>3</sup>/tonne) the section modulus is to be based on a stress of 113 N/mm<sup>2</sup> (1150 kgf/cm<sup>2</sup>) assuming 100 per cent fixity.
- (b) When the hatch side girder supports four or more point loads from deck transverses, or an evenly distributed load:—

$$\frac{I}{y} = 5,20 b h S^2 \text{ cm}^3$$

#### Hatch End Beams

1309 Where the deck is transversely framed, hatch end beams supported at the centreline and carrying hatch side coamings and longitudinal girders in line, are to have a section modulus not less than:—

$$\frac{I}{y} = 19 K_1 S (S_1 b_1 h + S_2 b_2 h) + z_1 \text{ cm}^3$$

where  $S$  = span of hatch end beam, in metres, see 1301,

$S_1$  = span of hatch side girder, in metres,

$b_1$  = mean width, in metres, of deck and hatchway supported by hatch side girder,

$S_2$  = span of the adjacent longitudinal girder in line, in metres,



$b_2$  = mean width, in metres, of deck supported by the adjacent longitudinal girder in line,

$z_1$  = an increase dependent upon the constructional arrangement between the hatch openings, *see* 1310,

$b_h$  = breadth of hatchway, in metres,

$K_1$  = a factor obtained from Table D 13.1.

**1310** If there is an additional longitudinal girder situated inboard of the line of hatch side girder and between the hatches then:—

$$z_1 = 19 K_1 S (S_4 b_4 h) \text{ cm}^3$$

where  $S_4$  = span of the additional longitudinal girder, in metres,

$b_4$  = mean width, in metres, of deck supported by the additional longitudinal girder,

$K_1$  = a factor obtained from Table D 13.1 but taking  $b_h$  equal to twice the distance between the ship's centreline and the additional longitudinal girder.

TABLE D 13.1

$\frac{b_h}{2S}$	$K_1$
0,20	0,143
0,30	0,177
0,40	0,191
0,50	0,187
0,60	0,179
0,70	0,169
0,80	0,141
0,90	0,085
1,00	0

**1311** When the deck is framed longitudinally, the hatch end beam is to have a section modulus not less than that required by (a) or (b) below.

(a) When there are no transverses between the hatch end beam and the adjacent transverse bulkhead or equivalent support structure:—

$$\frac{I}{y} = 19 K_1 S (S_1 b_1 h) + 2,37 b_3 h S^2 \text{ cm}^3$$

where  $b_3$  = distance, in metres, between the hatch end beam and the adjacent transverse bulkhead or equivalent support structure,

$K_1$ ,  $S$ ,  $S_1$  and  $b_1$  are as defined in 1309.

(b) When there are one or more transverses between the hatch end beam and the adjacent transverse bulkhead or equivalent support structure:—

$$\frac{I}{y} = 19 K_1 S (S_1 b_1 h + S_3 b_1 h) \text{ cm}^3$$

where  $S_3$  = distance, in metres, between the hatch end beam and adjacent transverse bulkhead or equivalent support structure,

$K_1$ ,  $S$ ,  $S_1$  and  $b_1$  are as defined in 1309.

#### Inertia

**1312** The moment of inertia of deck girders is not to be less than:—

$$I = K_2 \frac{I}{y} S \text{ cm}^4$$

where  $k_2$  = 2,3 for weather deck hatch side girders,  
1,85 for other longitudinal girders,  
2,8 for hatch end beams,

$\frac{I}{y}$  = Rule section modulus of the girder, in  $\text{cm}^3$ .

**1313** End connections of girders, deck transverses and hatch end beams are to be as required by D 1610.

For welding requirements, *see* Table D 32.1.

#### Effective Flange

**1314** The effective area of the attached deck plating to be included in the section modulus calculation for symmetrical and unsymmetrical girders (including weather deck hatch coamings) and box girders, is to be calculated as given in D 128.

For minimum thickness of deck plating in association with girders, *see* D 418.

#### Details

**1315** Girders of asymmetrical section are to be supported by tripping brackets at alternate beams or equivalent; if the section is symmetrical the brackets may be four frame spaces apart. Where the ratio of the unsupported width of the girder face flat or flange to its thickness is 16 or greater, the tripping brackets are to be connected to the face flat or flange. On girders of symmetrical section tripping brackets are to be fitted on both sides when they are required to be connected to the flange. Intermediate beams are to be connected to the girder by welding or by lugs.

If the girder is not continuous between bulkheads, the part which is under the deck is to be extended beyond the

end point of support for at least two frame spaces before commencing tapering off the web depth.

**1316** Continuity is to be efficiently maintained over the heads of pillars, and tripping brackets fitted in way.

**1317** At the corners of all hatchways supported by hatch end beams, horizontal gusset plates are to be fitted connecting the side girders to the hatch end beams. The gusset plates should taper off in the fore and aft direction over not less than one frame space; the taper outboard is to be over a similar distance and inboard not less than 450 mm. The thickness is to be not less than the maximum thickness of the face flats being connected.

**1318** Weather deck deep hatch coamings acting as girders should be extended beyond the hatchway ends in the form of brackets, the coamings below the deck are to be effectively connected to the hatch end beams.

Where extension above the deck is not practicable, the coaming below the deck is to be extended at least two frame spaces beyond the hatch end beams.

#### Additional Loads

**1319** Where a girder is subject to concentrated loads, such as pillars out of line, the scantlings are to be suitably increased, *see* D 25.

Where concentrations of loading on one side of the girder may occur, the girder should be adequately stiffened against torsion.

Additional attachments may be required to meet particular local stresses.

**1320** Where cargoes such as chilled meat are suspended from a deck which may be simultaneously loaded above, the scantlings of the girders are to be increased in accordance with D 603, D 605, D 807 and D 810.

#### Timber Deck Cargoes

**1321** Where timber load lines are to be assigned, *see* D 25.

#### Grades of Steel

**1322** For special steel requirements in girder webs on refrigerated ships, *see* D 427.

#### Cross-references

**1323** For cantilevers, *see* D 15.

D 1316 - D 1402

### Section 14

#### PILLARS AND NON-WATERTIGHT PILLAR BULKHEADS

##### Symbols

**1401**  $P$  = load, in kN (tonne-f), supported by the pillar and is to be equal to

$$\frac{9,81Sb_d h}{\rho} + P_a \quad \left( \frac{Sb_d h}{\rho} + P_a \right)$$

but not less than 19,62 kN (2 tonne-f),

$S$  = distance, in metres, between the centres of the two adjacent spans of girder supported by the pillar,

$b_d$  = mean width of deck, in metres, including hatchway if necessary, supported by the girders,

$h$  = head, in metres, supported by pillar, obtained from D 806, D 809, D 1306 and D 2515,

$P_a$  = load, in kN (tonne-f), from pillar or pillars above (zero if no pillar above),

$\rho$  = stowage rate and is to be taken as 1,39 m<sup>3</sup>/tonne unless specified otherwise,

$A$  = cross-sectional area of pillar, in cm<sup>2</sup>,

$l$  = overall span of pillar, in metres,

$l_e$  = effective span of pillar, in metres,

where  $l_e = 0,65l$  for hold pillars and  $0,8l$  for 'tween deck pillars,

$r$  = minimum radius of gyration of pillar cross-section, in mm,

$d_p$  = mean diameter of tubular pillar, in mm.

#### PILLARS

**1402** The sectional area of pillars is not to be less than:—

$$A = \frac{P}{12,36 - 51,5 \frac{l_e}{r}} \text{ cm}^2$$

$$\left( A = \frac{P}{1,26 - 5,25 \frac{l_e}{r}} \text{ cm}^2 \right)$$

As a first approximation,  $A$  may be taken as  $\frac{P}{9,32}$  and the radius of gyration estimated for a suitable  $\left( \frac{P}{0,95} \right)$



section having this area. If the area calculated using this radius of gyration differs by more than 10 per cent from the first approximation, a further calculation using the radius of gyration corresponding to the mean area of the first and second approximations is to be made.

For tubular pillars the wall thickness is not to be less than:—

$$t = \frac{P}{0,392 d_p - 4,9 l_e} \text{ mm, or } \frac{d_p}{40} \text{ mm}$$

$$\left( t = \frac{P}{0,04 d_p - 0,5 l_e} \text{ mm, or } \frac{d_p}{40} \text{ mm} \right)$$

whichever is the greater.

**1403** Where pillars support eccentric loads they are to be strengthened for the additional bending moment imposed upon them.

**1404** For the sides of hollow square pillars or web plates of channel or I sections the ratio of the breadth to the thickness is not to exceed:—

$$600 \frac{l_e}{r} \text{ or } 55$$

whichever is the greater.

The thickness of tubular and hollow square pillars is to be not less than 7,5 mm.

For ordinary angle or channel sections the ratio of the breadth to the thickness of the flanges is not to exceed:—

$$200 \frac{l_e}{r} \text{ or } 18$$

whichever is the greater.

For fabricated sections or the flanges of I section pillars the ratio of the breadth to the thickness of face plates is not to exceed:—

$$400 \frac{l_e}{r} \text{ or } 36$$

whichever is the greater.

#### General

**1405** Pillars are to be fitted in the same vertical line wherever possible and effective arrangements are to be made to distribute the load at the heads and heels of all pillars.

**1406** Tubular and hollow square pillars are to be attached at their heads to plates supported by brackets, flanged where necessary, in order to transmit the load effectively. Doubling or insert plates are to be fitted to the inner bottom under the heels of tubular or hollow square pillars, and to decks under large pillars.

The pillars are to have a bearing fit and are to be attached to the head and heel plates by continuous welding.

**1407** At the heads and heels of pillars built of rolled sections, the load is to be well distributed by means of longitudinal and transverse brackets.

**1408** In double bottoms under widely spaced pillars, the connections of the floors to the girders and of the floors and girders to the inner bottom are to be suitably increased. Where pillars are not directly above the intersection of plate floors and girders, partial floors and intercostals are to be fitted as necessary to support the pillars. Manholes are not to be cut in the floors and girders below the heels of pillars.

Where longitudinal framing is adopted in the double bottom, equivalent stiffening under the heels of pillars is to be provided.

**1409** Where the heels of pillars are carried on a tunnel, suitable arrangements are to be made to support the load.

**1410** Where pillars are fitted inside tanks or under watertight flats, the tensile stress in the pillar and its end connections is not to exceed 108 N/mm<sup>2</sup> (1100 kgf/cm<sup>2</sup>). In general, such pillars should be of built sections.

**1411** Pillars are to be fitted below deckhouses, windlasses, winches, capstans and elsewhere where considered necessary. The structure in way of the boat davits is to be strengthened.

**1412** Arrangements for supporting the structure in machinery spaces will be considered.

For pillars under forecastles in tankers, see D 5437.

#### Timber Deck Cargoes

**1413** Where timber load lines are to be assigned, the head to be used when calculating weather deck pillars is to be in accordance with D 1321.

#### NON-WATERTIGHT PILLAR BULKHEADS

**1414** The thickness of bulkhead plating is not to be less than 7,5 mm in holds and 6,5 mm in 'tween decks.

**1415** Stiffeners are to be spaced not more than 1500 mm apart.

1416 Stiffeners or corrugations are not to be less in depth than 150 mm in holds and 100 mm in 'tween decks.

1417 Rolled or built sections, swedges or symmetrical corrugations supporting deck beams, longitudinals, girders or transverses are to have a sectional area  $A$ , in  $\text{cm}^2$ , (including associated plating) not less than stated below:—

For rolled or built sections or swedges:

(a) where  $\frac{s}{t}$  is 80 or less,  $A$  as determined from 1402.

(b) where  $\frac{s}{t}$  lies between 80 and 120,  $A$  as determined by interpolation between the values obtained from 1402 and (c).

(c) where  $\frac{s}{t}$  is 120 or more,

$$A = \frac{P}{4,9 - 14,7 \frac{l_e}{r}} \text{ cm}^2$$

$$\left( A = \frac{P}{0,5 - 1,5 \frac{l_e}{r}} \text{ cm}^2 \right)$$

where  $s$  = stiffener spacing, in mm,

$t$  = thickness of associated flat plating, in mm,

$$r = 10 \sqrt{\frac{I}{A}} \text{ mm},$$

$I$  = inertia, in  $\text{cm}^4$ , of stiffener and associated plating.

As a first approximation,

$$A \text{ may be taken as } \frac{P}{3,92} \left( \frac{P}{0,4} \right)$$

For symmetrical corrugations:

(d) where  $\frac{b}{t_p}$  does not exceed  $\frac{750\lambda}{(\lambda + 0,25) r}$ ,

$A$  as determined from 1402.

(e) where  $\frac{b}{t_p}$  exceeds  $\frac{750\lambda}{(\lambda + 0,25) r}$ ,

$$A = \frac{P}{4,9 - 14,7 \frac{l_e}{r}} \text{ cm}^2$$

$$\left( A = \frac{P}{0,5 - 1,5 \frac{l_e}{r}} \text{ cm}^2 \right)$$

where  $b$ ,  $c$ ,  $d_w$ ,  $t_p$  and  $p$  are as shown in Fig. D 1.2, in mm, and

$$\lambda = \frac{b}{c}$$

$$r = d_w \sqrt{\frac{3b + c}{12(b + c)}} \text{ mm}$$

As a first approximation,

$$A \text{ may be taken as } \frac{P}{3,92} \left( \frac{P}{0,4} \right)$$

1418 The connections of bulkheads to deck and inner bottom are to be in accordance with Table D 32.1.

## Section 15

### CANTILEVERS

1501 This Section gives the required scantlings for cantilevers and their supporting frames. Section moduli for cantilevers not at hatch sides are given in 1503. Section moduli for hatch side cantilevers are given in 1504 and 1505. The remaining paragraphs in this Section refer to all cantilevers.

#### Symbols

1502

$\left( \frac{I}{y} \right)_1, \left( \frac{I}{y} \right)_2, \left( \frac{I}{y} \right)_3$  = mean of section moduli, in  $\text{cm}^3$ , of hatch end beams calculated for the positions shown in Fig. D 15.2,

$\left( \frac{I}{y} \right)_{s_1}$  = section modulus, in  $\text{cm}^3$ , of hatch side girder,

$\left( \frac{I}{y} \right)_{s_2}$  = mean of section moduli, in  $\text{cm}^3$ , of longitudinal girders in line with hatch side girder.  $\left( \frac{I}{y} \right)_{s_2}$  is not to be taken greater than  $\left( \frac{I}{y} \right)_{s_1}$ .

$\left( \frac{I}{y} \right)_u$  = section modulus, in  $\text{cm}^3$ , of frame or stiffener above cantilever. When there are no frames or stiffeners above cantilevers,  $\left( \frac{I}{y} \right)_u = 0$ .



$$\beta = \frac{c}{l}$$

$\rho$  = stowage rate, and is to be taken as 1,39 m<sup>3</sup>/tonne unless specified otherwise,

$$E = \frac{4}{n+1} \left[ \left\{ \left( \frac{I}{y} \right)_1 + \left( \frac{I}{y} \right)_2 \right\} + \frac{2u}{b} \left\{ \left( \frac{I}{y} \right)_2 + \left( \frac{I}{y} \right)_3 \right\} \right]$$

where centreline bulkheads or centreline pillars are fitted,

$$E = \frac{4}{n+1} \left[ \left( \frac{I}{y} \right)_1 + \left( \frac{I}{y} \right)_2 \right] \text{ where there is no support at the centreline,}$$

$$G = \frac{7u}{(n+1)c} \left[ \left( \frac{I}{y} \right)_{s_1} + \left( \frac{I}{y} \right)_{s_2} \right]$$

$$G_1 = \frac{3,5 u}{s} \left( \frac{I}{y} \right)_{s_1}$$

$M$  = bending moment, in kN m (tonne-f m), due to the load supported by a single cantilever. This bending moment is to be calculated about an axis distant  $u$  from hatch side, and for hatch side cantilevers with uniformly distributed loading it will be

$$\frac{4,9 su}{\rho} (h_1 b + h_2 u) \\ \left( \frac{su}{2\rho} (h_1 b + h_2 u) \right),$$

$c$  = distance, in metres, between hatch end beams,

$$Z = \frac{f}{u} \left( \frac{I}{y} \right)_c$$

$h_1$  = mean height, in metres, of cargo space above hatchway. At weather decks, see D 806.

$h_2$  = mean 'tween deck height, in metres, clear of hatchway. At weather decks, see D 806,

$l$  = distance, in metres, between transverse bulkheads. Where there is no bulkhead between hatchways,  $l$  is to be measured to a point midway between hatchways,

$n$  = number of cantilevers between the hatch end beams,

$s$  = cantilever spacing, in metres,

$A_f$  = sectional area, in cm<sup>2</sup>, of cantilever bracket face plate,

$d$  = web depth of cantilever or frame, in mm,

$d_c$  = root depth, in mm, of cantilever, as indicated in Fig. D 15.1,

$b, f, u, v$  and  $H$  are measured, in metres, as shown in Figs. D 15.1 and D 15.3.

$t, d_f$  and  $e$  are measured, in mm, as shown in Fig. D 15.1.

Note. The dimensions shown in Fig. D 15.1 are for calculating the second deck cantilevers. When other decks are being considered the deck indicated as "2nd Deck" is to be considered as the deck in question.

#### Cantilevers not at Hatch Sides

1503 The section modulus of cantilevers  $\left( \frac{I}{y} \right)_o$  at distance  $u$  from the outer end is not to be less than:—

$$\left( \frac{I}{y} \right)_o = 8,67M \text{ cm}^3 \quad \left( \left( \frac{I}{y} \right)_o = 85M \text{ cm}^3 \right)$$

The section modulus of supporting frames or stiffeners at distance  $v$  from the lower end is not to be less than:—

$$\left( \frac{I}{y} \right)_l = \frac{v}{H} \left[ \frac{f}{u} \left( \frac{I}{y} \right)_o - \left( \frac{I}{y} \right)_u \right] \text{ cm}^3$$

#### Hatch Side Cantilevers

##### 1504

##### (a) Uniform Loading

The section modulus of cantilevers,  $\left( \frac{I}{y} \right)_c$ , at distance  $u$  from the hatch side is not to be less than:—

A Hatch corners supported by Rule hatch end beams or pillars at hatch corners (see 1505, Note 5).

$$\left( \frac{I}{y} \right)_c = 0,9 \left( \frac{I}{y} \right)_o - G \text{ cm}^3$$

B Transverse bulkheads between hatchways. No Rule hatch end beams or pillars at hatch corners.

As required by A

or

$$\frac{n+1}{n} \left[ 0,45 \left( 1 + \frac{1}{\beta} \right) \left( \frac{I}{y} \right)_o - \beta G - (1 - \beta) E \right] \text{ cm}^3$$

whichever is the greater.

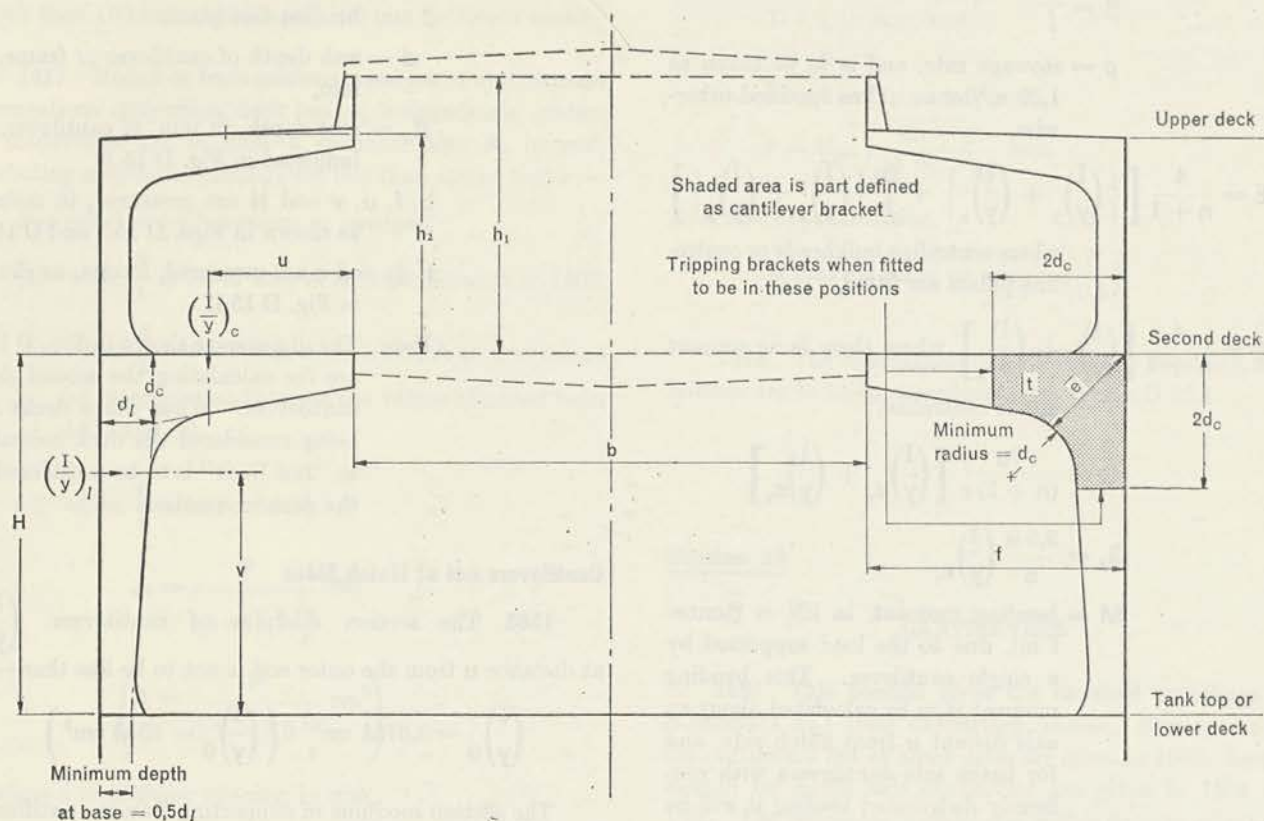


FIG. D 15.1

**C No transverse bulkheads between hatchways. No Rule hatch end beams or pillars at hatch corners.**

As required by A

or

$$\frac{n+1}{n} \left[ \frac{1}{\beta} \left( \frac{I}{y} \right)_o - 0.5 E \right] \text{ cm}^3$$

whichever is the greater.

$\left( \frac{I}{y} \right)_o$  is to be determined from 1503 and M is to be

calculated using a load which is the average of that supported by each cantilever. See also Notes to 1505.

**(b) Concentrated Loading**

The requirements in 1504 (a) are based on the assumption that cantilevers are approximately equally spaced and equally loaded. Where a particular cantilever is subjected

to concentrated loading, its modulus is to be that given by the following formula or as required by 1504 (a) whichever is the greater:—

$$\left( \frac{I}{y} \right)_c = \left( \frac{I}{y} \right)_o - G_1 \text{ cm}^3$$

where  $\left( \frac{I}{y} \right)_o$  is to be determined from 1503, and M is to be calculated using the particular load on the cantilever being considered.

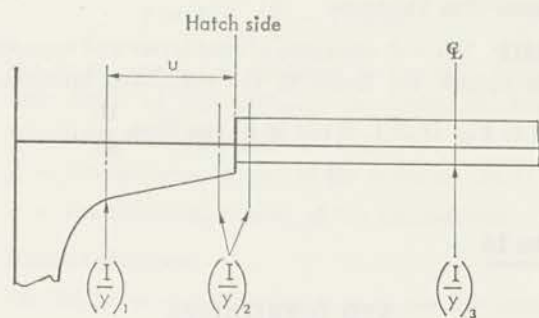
**Frames supporting Hatch Side Cantilevers**

**1505** The section modulus, at a distance v above the tank top or lower deck, of frames supporting cantilevers is not to be less than:—

$$\left( \frac{I}{y} \right)_l = \frac{v}{H} \left[ \frac{f}{u} \left( \frac{I}{y} \right)_c - \left( \frac{I}{y} \right)_u \right] \text{ cm}^3$$

where  $\left( \frac{I}{y} \right)_c$  is to be determined from 1504.





$(\frac{I}{Y})_2$  is the smaller modulus of the sections adjacent to the hatch side

FIG. D 15.2

**Notes**

The following Notes apply to 1504 and 1505:—

1. Where a transverse bulkhead is fitted at one end only of a hatchway, the section moduli of cantilevers and supporting frames are to be the mean of the values obtained from B and C.
2. Where the only cantilevers in the length of a hatchway consist of two or three on adjacent frames at mid-length, the sum of the moduli of the cantilevers should

be equal to that required for a single cantilever at mid-length.

3. If a negative value is calculated for the required section modulus, cantilevers are not necessary with the arrangement considered.

4. In calculating the actual section modulus of a cantilever or supporting frame, the effective area of attached plating is to be as given in D 128. Intermediate beams or frames within the effective breadth may be included in the calculation.

5. Rule hatch end beams are those with scantlings determined from D 13, assuming the hatch side girder has a span between hatch end beams.

**GENERAL**

**1506** The section modulus of side frames supporting cantilevers is not to be less than that required by D 7 for side frames in the same position. The section modulus of cantilever beams is not to be less than that required by D 8 for beams in the same position. The scantlings of pillars or pillar bulkhead stiffeners supporting cantilevers must also comply with D 14.

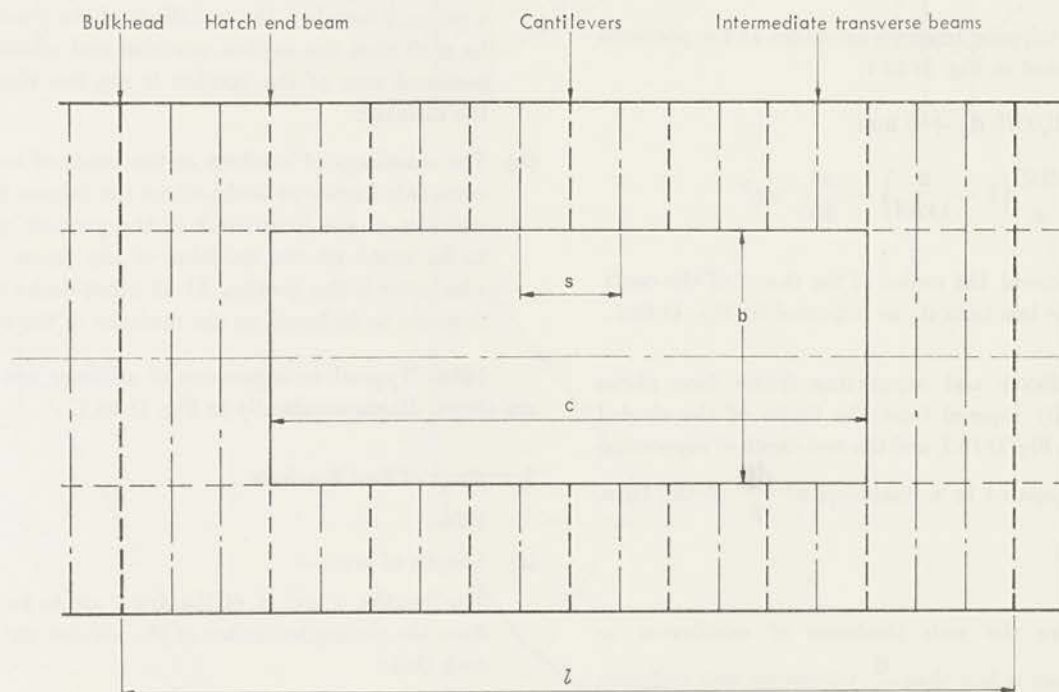


FIG. D 15.3

The modulus of hatch side coamings or girders is not to be less than that required by D 1307 or D 1308 taking the span between the cantilevers.

### Inertia

1507 The moment of inertia of cantilever beams at distance  $u$  from the hatch side or end of the cantilever is not to be less than:—

$$I = 9u \left( \frac{I}{y} \right)_c \text{ cm}^4$$

$\left( \frac{I}{y} \right)_c$  is the Rule section modulus at the same position.

### Cantilever Brackets

1508 The minimum thickness,  $t$ , of cantilever brackets and the minimum sectional area,  $A_f$ , of bracket face plates are to extend at least to the limits of the shaded portion shown in Fig. D 15.1 and are to be:—

(a) when tripping brackets are not fitted,

$$t = 0,0075 d_c + 5 \text{ mm}$$

$$A_f = \frac{27Z}{e} \left( 1 - \frac{e}{1420f} \right) - \frac{et}{300} \text{ cm}^2$$

(b) when tripping brackets are fitted at the positions indicated in Fig. D 15.1,

$$t = 0,0075 d_c + 5 \text{ mm}$$

$$A_f = \frac{20Z}{e} \left( 1 - \frac{e}{1420f} \right) - \frac{et}{200} \text{ cm}^2$$

1509 In general, the radius at the throat of the cantilever is not to be less than  $d_c$  as indicated in Fig. D 15.1.

1510 Cantilever and supporting frame face plates may be gradually tapered from the limits of the shaded portion shown in Fig. D 15.1, and the web depth of supporting frames may be tapered to a minimum of  $\frac{d}{2}$  at the base.

### Web Stiffening

1511 Where the web thickness of cantilevers or supporting frames is less than  $\frac{d}{60}$ , transverse web stiffeners should be fitted spaced approximately  $1,5d$  apart. Where stiffeners are fitted parallel to the face plates, the stiffening arrangements will be considered.

### Minimum Web Thickness

1512 The web thickness of cantilevers and supporting frames outside the limits of the cantilever brackets, as shown in Fig. D 15.1, is not to be less than  $\frac{d}{85}$ .

## Section 16

### END CONNECTIONS

#### General

1601 Primary members and secondary stiffening forming part of the hull structure are to be connected at their ends in accordance with the requirements of this Section, except where specifically permitted otherwise by the Rules.

1602 Where end connections are fitted in accordance with these requirements, they may be taken into account in determining the effective span of the member. See also D 130.

#### Stiffener End Brackets

##### 1603

- (a) Where a longitudinal strength member is connected to a primary member, the scantlings of the bracket are to be such that the section modulus and effective cross-sectional area of the bracket is not less than that of the member.
- (b) The scantlings of brackets at the heads of main transverse side frames at decks where the frames terminate, and also at the lower deck in the panting region, are to be based on the modulus of the frame or beam, whichever is the greater. At all other decks the scantlings are to be based on the modulus of the beam.

1604 Typical arrangements of stiffener end brackets are shown diagrammatically in Fig. D 16.1.

#### Scantlings of End Brackets

##### 1605

- (a) Length of arm:—

The lengths,  $a$  and  $b$ , of the arms, are to be measured from the plating to the toe of the bracket and are to be such that:

- (i)  $a+b \geq 2l$
- (ii)  $a \geq 0,8l$
- (iii)  $b \geq 0,8l$



where

$$l = 90 \left( \sqrt{\frac{Z}{t}} - 1 \right) \text{ mm}$$

but in no case is  $l$  to be taken as less than twice the web depth of the stiffener, on which the bracket scantlings are to be based,

$Z$  = the modulus, in  $\text{cm}^3$ , of the stiffener, (see D 125),

$t$  = the thickness, in mm, of the bracket web.

(b) Bracket thickness:—

The thickness of the bracket is to be not less than:

$$t = 3,5 + 0,25\sqrt{Z} \text{ mm}$$

but not less than 6,5 mm and need not be taken more than 12,5 mm. For minimum thickness for tankers, see D 4018.

The thickness of a bracket with unstiffened free edge is not to be less than 20 per cent greater than required by the above formula.

(c) Edge stiffening:—

Where the modulus of the stiffener exceeds  $500 \text{ cm}^3$ , or the length of free edge of the bracket exceeds  $50t \text{ mm}$ , the free edge of the bracket is to be stiffened.

Where a flange is fitted, the breadth of flange is to be not less than:

$$b_f = 40 \left( 1 + \frac{Z}{1000} \right) \text{ mm}$$

but not less than 50 mm.

Where the edge is stiffened by a welded face flat, the cross-sectional area of the face flat is to be not less than:

(i) for offset edge stiffening:

$$\text{Area} = 0,009 b_f t \text{ cm}^2$$

(ii) for symmetrically placed stiffening:

$$\text{Area} = 0,014 b_f t \text{ cm}^2$$

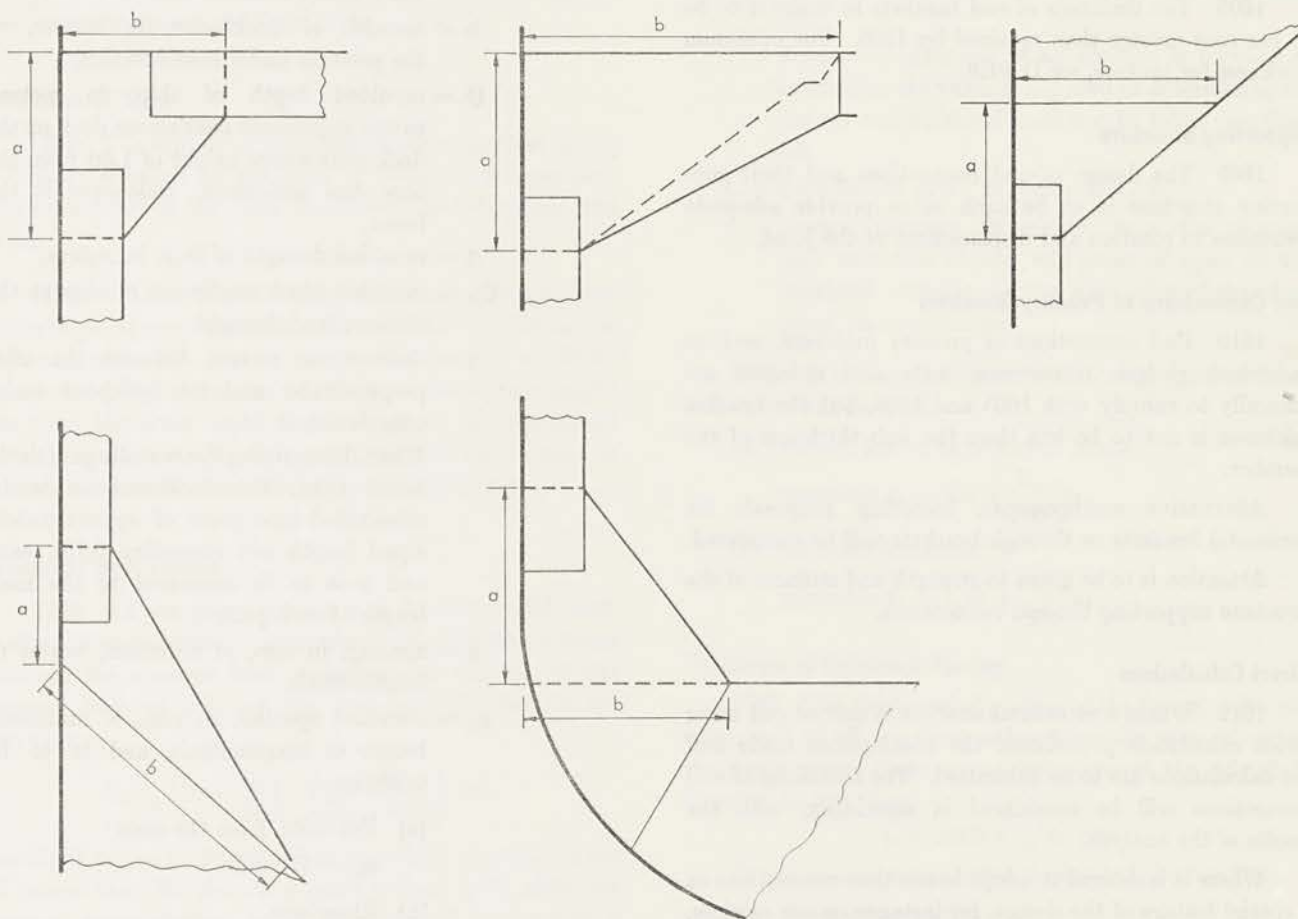


FIG. D 16.1 DIAGRAMMATIC ARRANGEMENTS OF STIFFENER END BRACKETS

**1606** Where the stiffening member is lapped on to the bracket, the length of overlap is to be adequate to provide for the required area of welding. *See* D 32.

In general, the length of overlap should not be less than  $10\sqrt{Z}$  mm, or the depth of stiffener, whichever is the greater.

The design of the overlap is to be such as to ensure that at no point in the connection is the modulus reduced to less than that of the stiffener with associated plating.

#### Brackets at Lower End of Main Transverse Side Framing

**1607** The length of arm of tank side and hopper side brackets is not to be less than 20 per cent greater than that required by 1605, and the edge is to be stiffened.

The modulus of the bracket (including effective area of shell plating) clear of the end of the main frame is not to be less than that of the main frame.

#### End Connections in Tanks

**1608** The thickness of end brackets in tanks is to be 10 per cent greater than required by 1605. For minimum thickness for tankers, *see* D 4018.

#### Supporting Structure

**1609** The design of end connections and their supporting structure is to be such as to provide adequate resistance to rotation and displacement of the joint.

#### End Connections of Primary Members

**1610** End connections of primary members, such as underdeck girders, transverses, webs and stringers are generally to comply with 1605 and 1606, but the bracket thickness is not to be less than the web thickness of the member.

Alternative arrangements, including proposals for horizontal brackets or through brackets will be considered.

Attention is to be given to strength and stiffness of the structure supporting the end connections.

#### Direct Calculations

**1611** Where a structural analysis is carried out using direct calculation procedures, the assumptions made and the calculations are to be submitted. The scantlings of end connections will be considered in association with the results of the analysis.

Where it is desired to adopt bracketless connections as a special feature of the design, for instance on car carriers, refrigerated ships, etc., then the proposals will be considered in each case.

#### Cross-references

**1612** For end connections of tanker primary structure, *see* D 51.

For welding of end connections, *see* Table D 32.3.

### Section 17

#### SUPERSTRUCTURES AND DECKHOUSES

##### Symbols

- 1701**  $L$  = length of ship, in metres,  
 $L_2$  = length of ship, in metres, but need not be taken greater than 250 m,  
 $L_3$  = length of ship, in metres, but need not be taken greater than 300 m,  
 $B$  = moulded breadth of ship, in metres,  
 $B_1$  = actual breadth of ship, in metres, at the section under consideration, measured at the weather deck,  
 $b$  = breadth of deckhouse, in metres, at the position under consideration,  
 $D$  = moulded depth of ship, in metres, to the uppermost continuous deck or the deck next above height of  $1,6d$  from the base line amidships, whichever is the lesser,  
 $d$  = moulded draught of ship, in metres,  
 $C_b$  = moulded block coefficient of ship at the summer load draught,  
 $x$  = distance, in metres, between the after perpendicular and the bulkhead under consideration  
 When determining the scantlings of deckhouse sides, the deckhouse is to be subdivided into parts of approximately equal length not exceeding  $0,15L$  each and  $x$  is to be measured to the mid-length of each part,  
 $s$  = spacing, in mm, of stiffeners, beams or longitudinals,  
 $s_b$  = standard spacing, in mm, of stiffeners, beams or longitudinals, and is to be taken as:—  
 (a) For  $0,05L$  from the ends  
 $s_b = 610$  mm  
 (b) Elsewhere  
 $s_b = 470 + \frac{L_2}{0,6}$  mm



but forward of  $0,2L$  from the fore perpendicular  $s_b$  is not to exceed 700 mm,

$S$  = span, in metres, of stiffeners, and is to be taken as the 'tween deck or house height but in no case less than 2,0 m.

$I$  = span, in metres, of deck beams or longitudinals.

### Application

**1702** The scantlings of exposed bulkheads and decks of superstructures and deckhouses are generally to comply with the following requirements, but increased scantlings may be required where the structure is subjected to additional loading.

Where there is no access from inside the house to below the freeboard deck, or where a bulkhead is in a particularly sheltered location, the scantlings may be specially considered.

The term "erection" is used in this Section to include both superstructures and deckhouses.

### Definition of Tiers

**1703** The lowest, or first, tier is normally that which is directly situated on the deck to which  $D$  is measured. The second tier is the next tier above the lowest tier and so on.

**1704** Where, however, the freeboard corresponding to the required summer moulded draught for the ship can be obtained when the ship is considered to have a virtual moulded depth at least one standard superstructure height less than the Rule depth  $D$  measured to the uppermost continuous deck, proposals to treat the first tier erection as a second tier, and so on, will be specially considered.

### Minimum Bow Height

**1705** All sea-going ships are to be fitted with forecastles, increased sheer or equivalent such that the distance between the summer load waterline and the top of the exposed deck at side (at the fore perpendicular) is not less than:—

$$56 L_2 \left( 1 - \frac{L_2}{500} \right) \left( \frac{1,36}{C_b + 0,68} \right) \text{ mm}$$

but  $C_b$  is not to be taken as less than 0,68. Forecastles are to extend from the stem to a point at least  $0,07L$  abaft the forward perpendicular, or, if the required bow height is obtained by means of increased sheer, the sheer is to extend for at least  $0,15L$  from the forward perpendicular.

### Design Pressure Head

**1706** The design pressure head to be used in the determination of erection scantlings is to be taken as:—

$$h = \alpha \delta (\beta \lambda - \gamma) m$$

where the terms of this expression are as follows:—

$\alpha$  = a coefficient given in Table D 17.1,

$\delta$  = 1,0 for exposed machinery casings and houses protecting openings to pump rooms,

$\delta = \left( 0,3 + 0,7 \frac{b}{B_1} \right)$  elsewhere, but is in no case to be taken less than 0,475,

$$\beta = 1,0 + \left( \frac{\left( \frac{x}{L} - 0,45 \right)^2}{(C_b + 0,2)} \right) \text{ for } \frac{x}{L} \leq 0,45$$

$$\beta = 1,0 + 1,5 \left( \frac{\left( \frac{x}{L} - 0,45 \right)^2}{(C_b + 0,2)} \right) \text{ for } \frac{x}{L} > 0,45$$

$C_b$  is not to be taken less than 0,6 nor greater than 0,8.

Where the after-end of an erection is forward of amidships, the value of  $C_b$  used in determining for the aft end bulkhead need not be taken less than 0,8.

$\lambda$  = a coefficient given in Table D 17.2,

$\gamma$  = vertical distance, in metres, from the summer load waterline to the mid-point of span of the bulkhead stiffener, or the mid-point of the plate panel, as appropriate.

**1707** In no case, however, is the design pressure head to be taken as less than:—

(a) Lowest tier of unprotected fronts:

$$\text{minimum } h = 2,5 + \frac{L_2}{100} \text{ m}$$

(b) All other locations:

$$\text{minimum } h = 1,25 + \frac{L_2}{200} \text{ m}$$

### Thickness of Bulkhead Plating

**1708** The thickness of plating of the fronts, sides and after ends of all erections, other than the sides of superstructures where these are an extension of the side shell, is not to be less than:—

$$t = 0,003 s \sqrt{h} \text{ mm}$$

In no case, however, is the thickness to be less than:

(a) For the lowest tier

$$t = 5,0 + \frac{L_3}{100} \text{ mm}$$

TABLE D 17.1 VALUES OF  $\alpha$ 

POSITION	$\alpha$
Lowest Tier—Unprotected Front	$2 + \frac{L_3}{120}$
Second Tier—Unprotected Front	$1 + \frac{L_3}{120}$
Third Tier and above—Unprotected Front All Tiers—Protected Fronts All Tiers—Sides	$0,5 + \frac{L_3}{150}$
All Tiers—Aft end where aft of amidships	$0,7 + \frac{L_3}{1000} - 0,8 \frac{x}{L}$
All Tiers—Aft end where forward of amidships	$0,5 + \frac{L_3}{1000} - 0,4 \frac{x}{L}$

(b) for the upper tiers

$$t = 4,0 + \frac{L_3}{100} \text{ mm but not less than } 5,0 \text{ mm}$$

1709 The thickness of sides of forecastles, bridges and poops is to be as required by D 5 or D 43 as appropriate.

#### Modulus of Stiffeners

1710 The modulus of stiffeners on front, side and end bulkheads of all erections, other than sides of superstructures is not to be less than:—

$$\frac{I}{y} = \frac{h s S^2}{285} \text{ cm}^3$$

1711 The modulus of side frames of forecastles, bridge and poops is to be as required by D 7.

#### End Connections of Stiffeners

1712 The end connections of stiffeners are to be as given in Table D 17.3.

#### Deck Plating

1713 The thickness of erection deck plating is not to be less than:—

(a) Forecastle deck

$$t = (0,017 L + 6) \sqrt{\frac{s}{s_b}} \text{ mm}$$

(b) Other first tier erections

$$t = 7,5 \sqrt{\frac{s}{s_b}} \text{ mm}$$

(c) Second tier erections

$$t = 7 \sqrt{\frac{s}{s_b}} \text{ mm}$$

(d) Third tier erections and above

$$t = 6,5 \sqrt{\frac{s}{s_b}} \text{ mm}$$

1714 When decks are fitted with approved sheathing, the thicknesses derived from 1713 may be reduced in accordance with D 425.

Inside deckhouses, the thickness may be reduced by a further 10 per cent.

#### Deck Beams and Longitudinals

1715 The section modulus of superstructure deck longitudinals or transverse beams is to be in accordance with the requirements of D 6 or D 8 as appropriate.

1716 Transverse deck beams in deckhouses, and deck longitudinals other than as in 1722, are to have a section modulus not less than:—

$$\frac{I}{y} = \frac{h_1 s l^2}{210} \text{ cm}^3$$



but the modulus is in no case to be less than:—

$$\frac{s}{40} \text{ cm}^3$$

The value of  $h_1$  is to be taken not less than:—

On first tier decks...	0,9 m
On second tier decks ...	0,6 m
On third tier decks and above ...	0,45 m

#### Deck Girders and Transverses

1717 The section modulus of deck girders and transverses is to be in accordance with the requirements of D 13.

#### Strengthening at Ends and Sides of Erections

1718 Web frames or partial bulkheads are to be fitted within bridges and poops which have large deckhouses or other erections above.

Web frames or equivalent strengthening are also to be arranged to support the sides and ends of large deckhouses. These web frames should be spaced about 9 m apart and are to be arranged, where practicable, in line with watertight bulkheads below. Webs are also to be arranged in way of large openings, boat davits and other points of high loading.

1719 Arrangements are to be made to minimize the effect of discontinuities in erections. All openings cut in the sides should be substantially framed and have well rounded corners. Continuous coamings or girders are to be fitted below and above doors and similar openings.

House tops are to be strengthened in way of davits.

Special care is to be taken to minimize the size and number of openings in the side bulkheads in the region of the ends or erections within 0,5L amidships.

Account is to be taken of the high vertical shear loading which can occur in these areas.

1720 Adequate support under the ends of erections is to be provided in the form of webs, pillars, diaphragms or bulkheads in conjunction with reinforced deck beams.

At the corners of houses and in way of supporting structures attention is to be given to the connection to the deck and doublers or equivalent arrangements should generally be fitted.

1721 The side plating of bridges having a length of 0,15L or greater is to be increased in thickness by 25 per cent at the ends of the structure and is to be tapered into the upper deck sheerstrake. This plating is to be efficiently

TABLE D 17.2 VALUES OF  $\lambda$

LENGTH L	$\lambda$	EXPRESSION FOR $\lambda$
metres		
90	6,03	$L \leq 150 \text{ m}$ $\lambda = \left[ \frac{L}{10} e^{-\frac{L}{300}} \right] - \left[ 1 - \left( \frac{L}{150} \right)^2 \right]$
110	7,16	
130	8,18	
150	9,10	
150	9,10	$150 \text{ m} < L < 300 \text{ m}$ $\lambda = \frac{L}{10} e^{-0,00333L}$
170	9,65	
190	10,08	
210	10,43	
230	10,69	
250	10,86	
270	10,98	
290	11,03	
300	11,03	
300 and above	11,03	$L \geq 300 \text{ m}$ $\lambda = 11,03$

stiffened at the upper edge and supported by web plates not more than 1,5 m from the end bulkhead.

Proposals for alternative arrangements, including the use of higher tensile steel, will be specially considered.

#### Erections Contributing to Hull Strength

**1722** Where a long superstructure or deckhouse is fitted extending within 0,5L amidships, the scantlings of the first tier deck plating and longitudinals may require to be increased. *See also* D 307.

#### Aluminium Deckhouses

**1723** When an aluminium alloy complying with P 12 is used in the construction of deckhouses, the scantlings of these erections are to be increased (relative to those required for steel construction) by the percentages given in Table D 17.4.

The thickness of aluminium alloy stiffening members is not to be less than:—

$$t = 2,5 + 0,022d_w \text{ mm but need not exceed } 10 \text{ mm,}$$

where  $d_w$  = depth of the section, in mm.

The minimum moment of inertia of aluminium alloy stiffening members is not to be less than:—

$$I = 5,25 \frac{I}{y} l_1 \text{ cm}^4$$

where  $l_1$  is the span of the member, in metres, and  $\frac{I}{y}$  is the section modulus of the stiffener and attached plating.

**1724** Where aluminium erections are arranged above a steel hull, details of the arrangements in way of the bimetallic connection are to be submitted.

**1725** *See* F 812 with regard to fire protection of aluminium erections.

TABLE D 17.3

POSITION	ATTACHMENT AT TOP AND BOTTOM
1. Front stiffeners of lower tiers and of upper tiers when L is 160 m or greater	<i>See</i> Table D 32.1, Note 7
2. Front stiffeners of upper tiers when L is less than 160 m	Unattached
3. Side stiffeners of lower tiers where two or more tiers are fitted	Bracketed, unless stiffener modulus is increased by 20 per cent and ends are welded to the deck all round
4. Side stiffeners if only one tier is fitted and aft end stiffeners of after deckhouses on deck to which D is measured	<i>See</i> Table D 32.1, Note 7
5. Side stiffeners of upper tiers when L is 160 m or greater	<i>See</i> Table D 32.1, Note 7
6. Side stiffeners of upper tiers when L is less than 160 m	Unattached
7. Aft end stiffeners except as covered by 4 above	Unattached
8. Exposed machinery and pump room casings: — Front stiffeners on amidship casings and all stiffeners on aft end casings which are situated on the deck to which D is measured	Bracketed
9. All other stiffeners on exposed machinery and pump room casings	6,5 cm <sup>2</sup> of weld



TABLE D 17.4

ITEM	PERCENTAGE INCREASE
Fronts, sides, after ends and unsheathed deck plating	20
Decks sheathed in accordance with D 425	10
Decks sheathed with wood and on which the plating is fixed to the wood sheathing at the centre of each beam space	Nil
Stiffeners and beams	70
Scantlings of small isolated houses	Nil

**Companionways, Doors and Accesses**

**1726** Companionways on exposed decks are to be of equivalent construction, weathertightness and strength to a deckhouse in the same position and effectively secured to the deck.

**1727** Access openings in:—

- (a) Bulkheads at ends of enclosed superstructures,
- (b) deckhouses or companionways protecting openings leading into enclosed superstructures or to spaces below the freeboard deck,
- (c) deckhouse on a deckhouse protecting an opening leading to a space below the freeboard deck,

are to be fitted with doors which are to be of steel or other equivalent material, permanently and strongly attached to the bulkhead, and framed, stiffened and fitted so that the whole structure is of equivalent strength to the unpierced bulkhead and watertight when closed. The doors are to be gasketed and secured weathertight by means of clamping devices or equivalent arrangements, permanently attached to the bulkhead or to the door. Doors are generally to open outwards and are to be capable of being operated and secured from both sides. The sill heights are to be as required by D 2646 and D 2647.

*See also* R(J) 302 concerning accesses in chemical carriers.

**1728** Elsewhere doors may be of hardwood not less than 50 mm in thickness or of equivalent material.

**1729** Direct access from the freeboard deck to the machinery space is not permitted on ships with freeboards of Types "A", "B-100" or "B-60". Doors may, however, be fitted in exposed machinery casings on these ships provided they lead to a space or passageway which is of equivalent

strength to the casing and is separated from the machinery space by a second weathertight door. *See also* D 2648.

**Skylights**

**1730** Skylights, where fitted, are to be substantially constructed and securely attached to their coamings.

The height of coaming is not to be less than 600 mm in position 1 and 450 mm in position 2 (*see* D 2605). Glasses, where fitted, are to be effectively protected against risk of mechanical damage. Skylights to machinery spaces are also to comply with the requirements of D 2112.

**Unusual Designs**

**1731** Where superstructures or deckhouses are of unusual design, additional strength may be required.

**Cross-references**

**1732** For increase in thickness of shell and deck plating at ends of superstructures, *see* D 4, D 5, D 42 and D 43.

**Section 18****WATERTIGHT BULKHEADS****Symbols****1801**

L = length of ship, in metres,

a = height in metres, of bracket or end stool or lowest strake of plating,

e = effective length, in metres, of bracket or end stool, as given in Tables D 18.3 and D 18.4,

$h, h_0$  = vertical distance, in metres, from the middle of span  $l, S$ , respectively, to a point 0,91 m above the bulkhead deck at side,

$$l = S - e_1 - e_2$$

= effective span, in metres, of stiffener or corrugation, (see Figs. D 18.1 and D 18.2),

$S$  = overall height, in metres, of bulkhead between support points (including brackets or end stools if fitted),

$\gamma = 1,4$  for double plate bulkheads and welded stiffeners other than flat bars,  
 $1,6$  for flat bar stiffeners and swedges,  
 $1,1$  for symmetrical corrugations,

$\omega$  = end constraint coefficient relating to the ends of the effective span  $l$ . Values of  $\omega$  lie between 0 and 1.

#### Number and Disposition of Transverse Watertight Bulkheads

**1802** All ships are to have a collision bulkhead, an after peak bulkhead generally enclosing the sterntubes in a watertight compartment, and a bulkhead at each end of the machinery space.

Additional watertight bulkheads are to be fitted so that the total number of bulkheads is in accordance with Table D 18.1.

**1803** The collision bulkhead on all ships is to be positioned as detailed in Table D 18.2. Consideration will, however, be given to proposals for the collision bulkhead to be positioned slightly further aft on type (2) ships, but not

TABLE D 18.1

LENGTH $L$		TOTAL NUMBER OF BULKHEADS	
EXCEEDING	NOT EXCEEDING	MACHINERY AMIDSHIPS	MACHINERY AFT*
metres	metres		
90	105	5	5
105	115	6	5
115	125	6	6
125	145	7	6
145	165	8	7
165	190	9	8
190		To be considered individually	

\*After peak bulkhead forming the after boundary of the machinery space.

TABLE D 18.2

## COLLISION BULKHEAD POSITION

LENGTH $L$		DISTANCE OF COLLISION BULKHEAD AFT OF FORE END OF SUMMER LOAD WATERLINE	
		MINIMUM	MAXIMUM
Type (1)	$\leq 200$ m	$0,05L$	$0,08L$
	$> 200$ m	10 m	$0,08L$
Type (2)	$\leq 200$ m	$0,05L - f_1$	$0,08L - f_1$
	$> 200$ m	$10 \text{ m} - f_2$	$0,08L - f_2$

more than  $0,08L$  from the fore end of the summer load waterline; provided that the application is accompanied by calculations showing that flooding of the space forward of the collision bulkhead will not result in any part of the freeboard deck becoming submerged, nor in an unacceptable loss of stability.

where  $f_1 = \frac{G}{2}$  or  $0,015L$ , whichever is the lesser,

$f_2 = \frac{G}{2}$  or 3 m, whichever is the lesser,

$G$  = projection of bulbous bow forward of fore end of summer load waterline, in metres.

Type (1) A ship that has no part of its underwater body extending beyond the fore end of the summer load waterline.

Type (2) A ship with part of its underwater body extending forward of the fore end of the summer load waterline (e.g. bulbous bow).

**1804** The bulkheads in the holds should be spaced at reasonably uniform intervals. Where this is departed from and the length of a hold is unusually great, the transverse strength of the ship is to be maintained.

**1805** The Committee will be prepared to consider proposals from Owners to dispense with one or more of these bulkheads if they interfere with the requirements of a special trade, subject to suitable structural compensation.

#### Height of Bulkheads

**1806** The collision bulkhead is normally to extend to the uppermost continuous deck or, in the case of ships with



a combined bridge and forecastle or a long superstructure which includes a forecastle, to the superstructure deck. However, if a ship is fitted with more than one complete superstructure deck, the collision bulkhead may be terminated at the deck next above the freeboard deck. Where the collision bulkhead extends above the freeboard deck, the extension need only be to weathertight standards.

**1807** The after peak bulkhead may terminate at the first deck above the load waterline, provided this deck is made watertight to the stern or to a watertight transom floor.

**1808** The remaining watertight bulkheads are to extend to the freeboard deck.

In passenger ships of restricted draught and all ships of unusual design, the height of the bulkheads will be specially considered.

#### Bulkhead Plating

**1809** The thickness of plating of watertight bulkheads which do not form the boundaries of tanks is not to be less than:—

$$t = 0,004 s \sqrt{h_1} \text{ mm}$$

unless  $\frac{1000S_1}{s}$  is less than 4, when the thickness obtained from the above formula is to be multiplied by the factor  $1,1 - \frac{s}{2500S_1}$

where  $s =$  (a) stiffener spacing, in mm, on plane or double plate bulkheads,

(b) breadth, in mm, of flange or web, whichever is the greater, for corrugated bulkheads,

(c) breadth of flat plating, in mm, for swedged bulkheads,

$h_1 =$  vertical distance, in metres, from a point one-third of the height of the plate above its lower edge, to a point 0,91 m, above the bulkhead deck at side,

$S_1 =$  overall length of stiffener between support points, in metres.

The thickness of collision bulkheads not forming the boundaries of tanks is to be 12 per cent greater than the thickness derived from the formula above.

The minimum thickness of bulkhead plating is to be 5,5 mm. Where the class notation includes a reference to ore cargoes the minimum thickness of the hold bulkheads is to be 10 mm.

#### Bulkhead Stiffeners

**1810** The scantlings of stiffeners of watertight bulkheads not forming boundaries of tanks are to be determined from 1814 for rolled or built stiffeners and swedges, and from 1815 for symmetrical corrugations and double plate bulkheads.

The section modulus of stiffeners of collision bulkheads not forming the boundaries of tanks is to be 25 per cent greater than that required for watertight bulkheads.

**1811** Where bulkhead stiffeners are cut in way of watertight doors in the lower part of a bulkhead, the opening is to be suitably framed and reinforced.

Where stiffeners are not cut but the spacing between the stiffeners is increased on account of watertight doors, as in 'tween deck bulkheads, the stiffeners at the sides of the doorways are to be increased in depth and strength so that the efficiency is at least equal to that of the unpierced bulkhead, without taking the stiffness of the door frame into consideration.

**1812** Bulkheads are to be suitably strengthened, if necessary, at the ends of deck girders and where subjected to concentrated loads.

**1813** The section modulus of swedges is to be calculated in association with 610 mm or the breadth of flat plating, whichever is the lesser.

#### Rolled or Built Stiffeners and Swedges

**1814** The section modulus of rolled or built stiffeners and swedges, calculated at the middle of span  $l$  on watertight bulkheads not forming boundaries of tanks is not to be less than:—

$$\frac{I}{y} = \frac{h s l^2}{71 \gamma (\omega_1 + \omega_2 + 2)} \text{ cm}^3$$

where  $s =$  spacing of stiffeners, in mm.

The ratio of the web depth to the web thickness is not to exceed 60 for stiffeners with flanges or face plates and 18 for flat bars.

#### NOTES

1. Various types of end connection are listed in Table D 18.3 and illustrated in Fig. D 18.1 for the corresponding type number, together with appropriate values of end constraint  $\omega$  and, where applicable, effective bracket length  $e$ . Subscripts 1 and 2 refer to top and bottom of stiffener respectively.

2. When a bulkhead consists of several spans of vertical stiffeners supported by 'tween decks or horizontal girders, it is recommended that the top span should be

**TABLE D 18.3**  
**ROLLED OR BUILT STIFFENERS AND SWEDGES**

END CONNECTION (see Fig. D 18.1)		TYPE	$\omega$	e	
End of stiffener unattached or attached to plating only		(1)	0	0	
Member in line at deck or at Rule horizontal girder	Adjacent member B of smaller section	(2)	$\frac{4,5}{M_1} \left( \frac{I}{y} \right)_B$ or 1*	0	
	Adjacent member B of same or larger section	(3)	1	0	
Bracketless connection to longitudinal member	Member A within length S	(4)	1	d <sub>A</sub>	
	Member A outside length S	(5)	1	0	
Bracketed	To transverse member	Bracket extends to floor	(6)	1	$\beta a$ or 0,1S*
		Otherwise	(7)	1	0
	To longitudinal member		(8)	1	$\beta a$ or 0,1S*

where  $\beta = 1$  for brackets with face bars directly connected to stiffener face bars,  
 $= 0,7$  for flanged brackets,  
 $= 0,5$  for unflanged brackets,

$d_A$  = depth, in metres, of supporting member A (see Fig. D 18.1),

$\left( \frac{I}{y} \right)_B$  = section modulus, in  $\text{cm}^3$ , of supporting member B,

$$M_1 = \frac{h s l^2}{71}$$

\*Where two values of  $\omega$  or e are given in the Table, the smaller is to be used.



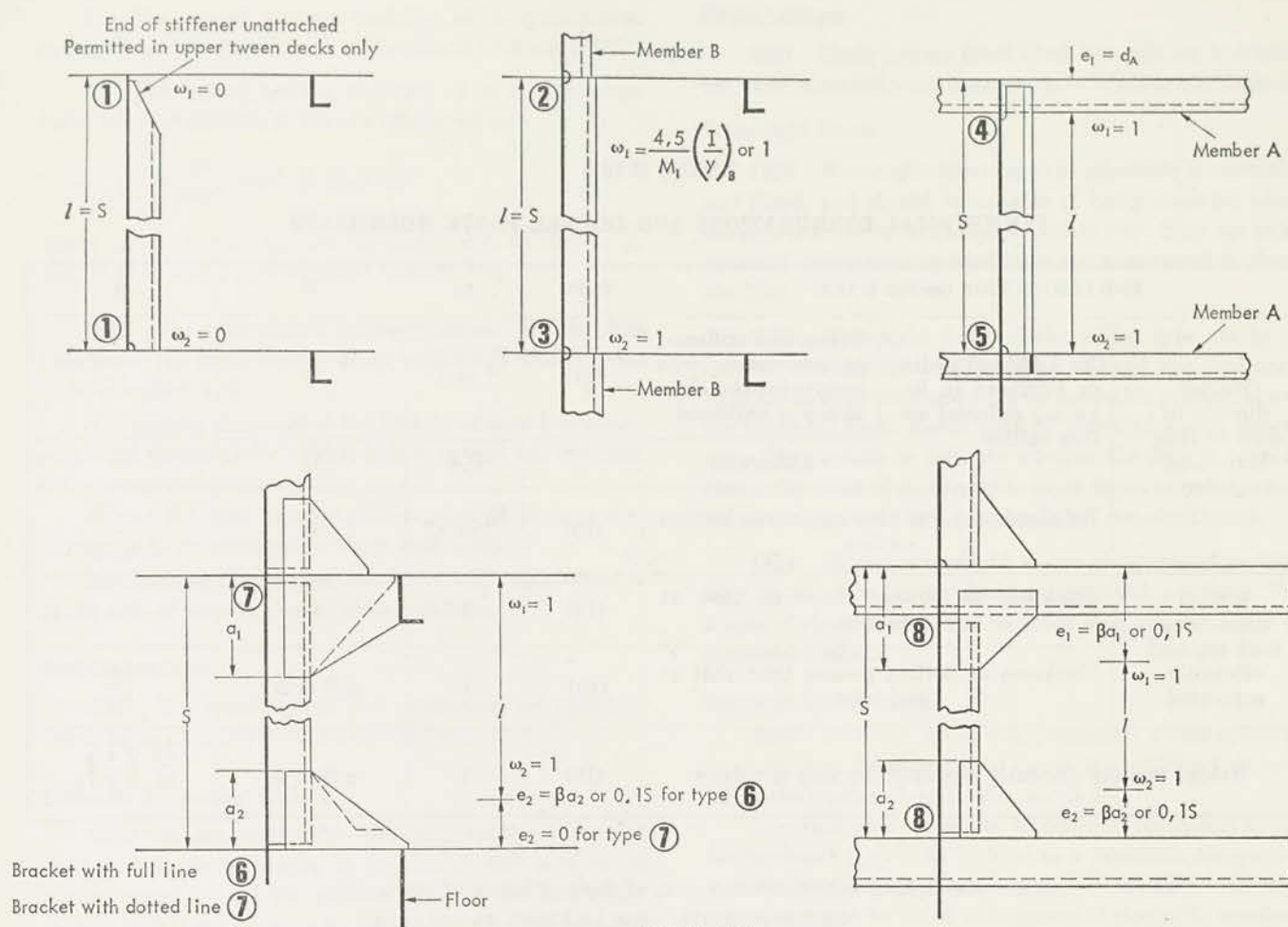


FIG. D 18.1

calculated first and then the other spans considered from the top span downwards.

3. For convenience of definition, Table D 18.3 implies vertical stiffening on transverse bulkheads. The Rules also apply to horizontal stiffening and longitudinal bulkheads, providing due regard is paid to the appropriate directions of end supporting members.

4. Bracketless connections type (4) may be made by welding the stiffening members "back to back" with as large an overlap as possible, or with the flanges on the same side, provided the web at the corner of the connection is suitably strengthened with a doubling plate or a diagonal stiffener.

#### Symmetrical Corrugations and Double Plate Bulkheads

1815 The section modulus of symmetrical corrugations and double plate bulkhead primary members,

calculated at the middle of span  $l$  on watertight bulkheads not forming boundaries of tanks, is not to be less than:—

$$\frac{I}{Y} = \frac{h p l^2}{71 \gamma (\omega_1 + \omega_2 + 2)} \text{ cm}^3$$

where  $p$  is the spacing of corrugations or vertical webs of double plate bulkheads (see Fig. D 1.2 or Fig. D 18.4 respectively).

#### NOTES

1. Various types of end connection are listed in Table D 18.4 and illustrated in Fig. D 18.2 for the corresponding type number, together with appropriate values of end constraint  $\omega$  and, where applicable, effective stool length  $e$ .

2. Subscripts 1 and 2 refer to top and bottom of bulkhead respectively.

**TABLE D 18.4**  
**SYMMETRICAL CORRUGATIONS AND DOUBLE PLATE BULKHEADS**

END CONNECTION (see Fig. D 18.2)			TYPE	$\omega$	e	$\mu$
Welded directly to deck or Rule horizontal girder	No bulkhead in line or bulkhead in line having different section outline	Transverse stiffeners in association with longitudinal brackets at top of bulkhead	(11)	$\frac{t_e}{t}$ or 1*	0	—
		Otherwise	—	0,1	0	—
	Bulkhead in line having same section outline		(13)	$\frac{t_B}{t}$ or 1*	0	—
Welded directly to tank top and efficiently supported	Thickness at bottom same as that at mid-span		(14)	1	0	—
	Thickness at bottom greater than that at mid-span		(15)	1	$\alpha S$ or a*	$\frac{t_e}{t}$
Welded to stool efficiently supported by ship structure			(16)	1	$\alpha S$ or a*	$\frac{10}{M_2} \left( \frac{I}{y} \right)_s$

where  $t, t_e$  = thickness, in mm, of flange plating of corrugation or double plate bulkhead, at mid-span or end respectively,

$t_B$  = thickness, in mm, of flange plating of member B, (see Fig. D 18.2),

$\alpha$  = coefficient given in Fig. D 18.3,

$\left( \frac{I}{y} \right)_S$  = modulus, in  $\text{cm}^3$ , of horizontal section of stool adjacent to deck or tank top over breadth  $p$ . All material continuous from top to bottom of the stool may be included in the calculation,

$$M_2 = \frac{h_o p S^2}{71}$$

\*Where two values of  $\omega$  or  $e$  are given in the Table, the smaller is to be used.



3. The actual section modulus of a symmetrical corrugation over spacing,  $p$ , may be calculated from D 127.

4. The actual section modulus of a double plate bulkhead over spacing,  $p$ , may be calculated as:—

$$\frac{I}{y} = \frac{d}{6000} (6fpt + dt_w) \text{ cm}^3$$

where  $d$ ,  $p$ ,  $t$  and  $t_w$  are in mm, and as shown in Fig. D 18.4, and  $f$  is determined from D 128.

**1816** For symmetrical corrugations and double plate bulkheads, the requirements given in Table D 18.5 are also to be complied with.

The plating thickness at the middle of span  $l$  of corrugated and double plate bulkheads is to extend not less than 0.2 $l$  metres above mid-span.

Where the span of corrugations exceeds 15 m a diaphragm is to be arranged at about mid-span.

Manholes and lightening holes should not be positioned at the ends of webs in double plate bulkheads.

#### End Connections

**1817** The scantlings of end connections of stiffeners are to be as required by D 16 and Table D 32.3.

#### Stiffeners Supporting Girders

**1818** Where watertight bulkhead stiffeners support deck girders, the stiffeners, in association with a width of plating equal to half the stiffener spacing, are to comply with D 1402, but are not to be less in strength than required by 1814 and 1817.

#### Watertight Recesses and Flats

**1819** Watertight recesses in bulkheads are generally to be so framed and stiffened as to provide strength and stiffness equivalent to the requirements for watertight bulkheads.

In collision bulkheads, any recesses or steps in the bulkhead are to fall within the limits of bulkhead positions given in 1803. Where the bulkhead is extended above the freeboard deck, then the extension need only be to weather-tight standards. If a step occurs at that deck, the deck need also only be to weathertight standards in way of the step, unless the step forms the crown of a tank, *see* D 1920.

**1820** Horizontal plating is to be 1 mm thicker than required by 1809 at a corresponding level.

The thickness of plating and scantlings of beams or longitudinals are not to be less than required by D 4, D 8 or D 6.

#### Chain Lockers

**1821** Chain lockers fitted abaft the collision bulkhead are to be watertight and the space is to be efficiently drained.

#### Watertight Doors

**1822** Watertight doors are to be efficiently constructed and fitted, and should be capable of being operated when the ship is listed up to 15 degrees either way. They are to be operated under working conditions and hose tested in place. *See* 1827.

**1823** Watertight doors of the sliding type are to be capable of being operated by efficient hand operated gear, both at the door itself and from an accessible position above the bulkhead deck. Means shall be provided at the remote operating position to indicate whether the door is open or closed. The lead of shafting is to be as direct as possible and the screw is to work in a gunmetal nut. *See also* D 2001.

**1824** Hinged watertight doors of approved pattern may be fitted in 'tween decks in approved positions. The hinges of these doors are to be fitted with gunmetal pins or gunmetal bushes.

#### Openings in Bulkheads

**1825** No doors, manholes, permanent access openings or ventilation ducts are to be cut in the collision bulkhead below the freeboard deck. *See also* E 262.

The number of openings in collision bulkheads above the freeboard deck is to be kept to a minimum compatible with the design and proper working of the ship. All such openings are to be fitted with means of closing to weather tight standards.

Certain openings below the freeboard deck are permitted in the remaining bulkheads, but these must be kept to a minimum and provided with means of closing to watertight standards. *See* 1822, 1823 and D 2001. All such openings are to be to the satisfaction of the Surveyor.

#### Testing

**1826** Watertight bulkheads including recesses and flats are to be hose tested on completion.

Peak bulkheads not forming boundaries of tanks are to be tested by filling the peaks with water to the level of the load waterline.

#### Passenger Ships

**1827** In passenger ships the number and construction of the watertight bulkheads and watertight doors will be specially considered. Each watertight door shall be tested by water pressure to a head up to the bulkhead deck. The test may be carried out either before or after the door is fitted. *See* F 801 and F 805.

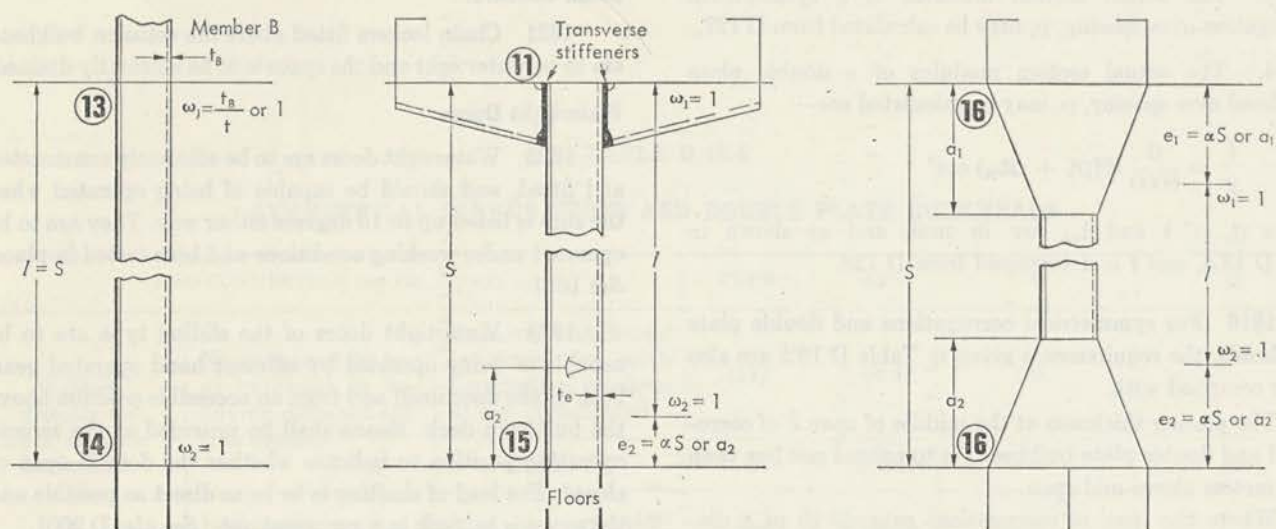


FIG. D 18.2

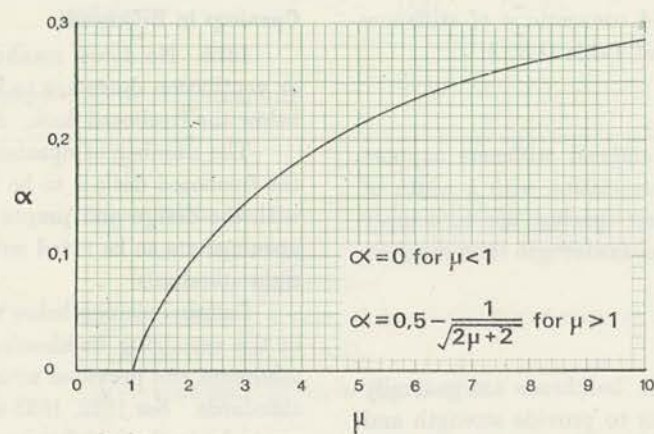


FIG. D 18.3

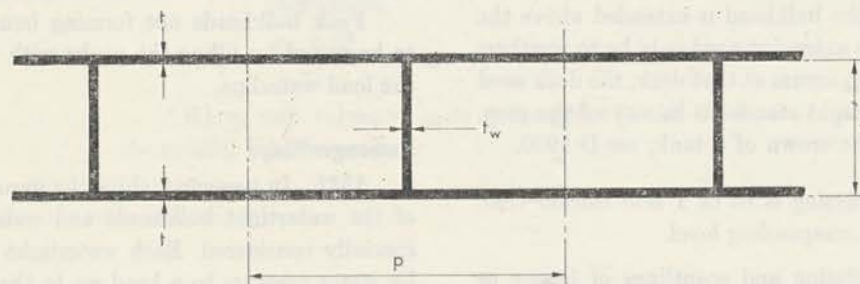


FIG. D 18.4



## Cross-references

1828 For peak and deep tanks, *see* D 19.

For watertight tunnels, *see* D 20.

For machinery casings in 'tween decks, *see* D 2109.

## Section 19

## PEAK, DEEP AND TOPSIDE TANKS

## General

1901 This Section gives the required scantlings for tanks carrying water, oil fuel for ship's use, or oil (including vegetable oil) and other liquids carried as cargo. When boundary bulkheads form part of the watertight subdivision of the ship, the requirements of D 18 are also to be satisfied.

1902 The scantlings of fore and after peak tanks are to be in accordance with D 54 and D 55 respectively.

1903 The flash point of oil fuel, or oil carried as cargo, is to be 60°C or above (closed cup test).

1904 Where tanks are intended for other liquid cargoes of a special nature the scantlings and arrangements will be considered in relation to the nature of the cargo.

## Structural Arrangements

1905 A centreline bulkhead is to be fitted in deep tanks which extend from side to side of the ship and are intended for the carriage of oil fuel for the ship's use.

1906 Centreline bulkheads may be intact or perforated as desired. If intact, the scantlings are to be as required for boundary bulkheads.

If perforated, the modulus of the stiffeners may be 50 per cent of that required for boundary bulkheads, using  $h$  measured to the crown of the tank. The stiffeners are to be bracketed at top and bottom. The area of perforation is to be not less than 5 per cent nor more than 10 per cent of the total area of the bulkhead.

When brackets from horizontal girders on the boundary bulkheads abut on the centreline bulkhead a light intercostal stringer is to be fitted at that level for the full length of the tank, or equivalent arrangements are to be provided.

## Plating

1907 The thickness of plating forming the boundaries of tanks is not to be less than:—

$$t = 0,004 s \sqrt{\frac{\rho h_2}{1,025}} + 2,5 \text{ mm}$$

TABLE D 18.5

TYPE OF BULKHEAD	PARAMETER	POSITION IN BULKHEAD	NOT TO EXCEED	NOT TO BE LESS THAN
Symmetrical corrugation	$\frac{b}{t_p}$	$\left\{ \begin{array}{l} \text{Top} \\ \text{Bottom} \end{array} \right.$	$\left\{ \begin{array}{l} 85 \\ 70 \end{array} \right.$	$\left\{ \begin{array}{l} — \\ — \end{array} \right.$
	$\theta$	All	—	40°
	$\frac{s}{t}$	$\left\{ \begin{array}{l} \text{Top} \\ \text{Bottom} \end{array} \right.$	$\left\{ \begin{array}{l} 75 \\ 65 \end{array} \right.$	$\left\{ \begin{array}{l} — \\ — \end{array} \right.$
Double plate	$\frac{d}{t_w}$	$\left\{ \begin{array}{l} \text{Top} \\ \text{Bottom} \end{array} \right.$	$\left\{ \begin{array}{l} 85 \\ 75 \end{array} \right.$	$\left\{ \begin{array}{l} — \\ — \end{array} \right.$
	$A_w$	Top	—	$\frac{0,12}{l} \frac{I}{y} \text{ cm}^2$
		Bottom	—	$\frac{0,18}{l} \frac{I}{y} \text{ cm}^2$

where  $\theta$  = angle of web of corrugation to plane of bulkhead (*see* Fig. D 1.2),

$d$  = depth, in mm, of double plate bulkhead (*see* Fig. D 18.4),

$s$  = spacing, in mm, of vertical stiffeners of double plate bulkhead,

$A_w$  = section area, in  $\text{cm}^2$ , of webs of double plate bulkhead.

unless  $\frac{1000 S_1}{s}$  is less than 4, when the thickness obtained from the above formula is to be multiplied by the factor:—

$$1,1 - \frac{s}{2500 S_1}$$

where  $s$  = stiffener spacing, in mm, on plane or double plate bulkheads, or

breadth, in mm, of flange or web, whichever is the greater, for corrugated bulkheads, or

breadth of flat plating, in mm, for swedged bulkheads,

$\rho$  = relative density (specific gravity) of the liquid to be carried and is not to be taken as less than 1,025,

$h_2$  = vertical distance, in metres, from a point one-third of the height of the plate above its lower edge to the top of the tank or half the distance to the top of the overflow, whichever is the greater,

$S_1$  = overall length of stiffener between support points, in metres.

The minimum thickness of plating is to be 7,5 mm.

#### Rolled or Built Stiffeners and Swedges

**1908** The section modulus and inertia of rolled or built stiffeners and swedges, calculated at the middle of span  $l$  on bulkheads forming tank boundaries, are not to be less than:—

$$\frac{I}{y} = \frac{h s l^2}{21,5 \gamma (\omega_1 + \omega_2 + 2)} \text{ cm}^3$$

$$\text{and } I = 2,3 \frac{I}{y} l \text{ cm}^4$$

The symbols used are as defined in D 1801 and D 1814 and the values of  $\omega$  and  $e$  are to be derived from Table D 18.3 except that:—

$h, h_0$  = vertical distance, in metres, from the middle of span  $l$ , or  $S$  respectively, to the top of the tank or half the distance, in metres, from the middle of the span to the top of the overflow, whichever is the greater.

Where the relative density (specific gravity),  $\rho$ , of the liquid to be carried exceeds 1,025, the values of  $h$  and  $h_0$  are to be multiplied by the

$$\text{factor } \frac{\rho}{1,025}$$

$$M_1 = \frac{h s l^2}{21,5}$$

The ratio of the web depth to the web thickness is not to exceed 60 for stiffeners with flanges or face plates and 18 for flat bars.

**1909** For swedges, the section modulus is to be calculated in association with 610 mm of attached plating or the breadth of flat plating, whichever is the lesser.

#### End Connections

**1910** Stiffener end connections are to be as required by D 1817.

NOTE. End connections of type (1) (see Fig. D 18.1) are not permitted at tank boundaries.

#### Symmetrical Corrugations and Double Plate Bulkheads

**1911** The section modulus of symmetrical corrugations and double plate bulkhead primary members, calculated at the middle of span  $l$  on bulkheads forming tank boundaries, is not to be less than:—

$$\frac{I}{y} = \frac{h p l^2}{21,5 \gamma (\omega_1 + \omega_2 + 2)} \text{ cm}^3$$

The symbols used are as defined in D 1801 and D 1815, and the values of  $\omega$  and  $e$  are to be derived from Table D 18.4, except that  $h$  and  $h_0$  are as defined in 1908 and

$$M_2 = \frac{h_0 p S^2}{21,5}$$

The depth  $d$  of symmetrical corrugations and double plate bulkheads is not to be less than:—

$$d = 39 l \text{ mm}$$

**1912** The section modulus of symmetrical corrugations and double plate bulkheads may be calculated as described in D 1815, Notes 3 and 4.

**1913** For symmetrical corrugations and double plate bulkheads forming tank boundaries, the requirements of Table D 19.1 are also to be complied with.

The plating thickness at the middle of span  $l$  of corrugated and double plate bulkheads is to extend not less than  $0,2l$  metres above mid-span.

Where the span of corrugations exceeds 15 m a diaphragm is to be arranged at about mid-span.

Manholes and lightening holes should not be positioned at the ends of webs in double plate bulkheads, unless suitable reinforcement is provided.

#### Stiffeners supporting Girders

**1914** Where stiffeners on bulkheads forming tank boundaries support deck beams, longitudinals, girders or transverses, the stiffeners, in association with a width of



plating equal to half the stiffener spacing, are to comply with D 1402 but are not to be less in strength than required by 1908 to 1910.

### Girders

**1915** The section modulus and moment of inertia of girders, when fitted, are not to be less than:—

$$\frac{I}{y} = 12 h b S^2 \text{ cm}^3$$

$$\text{and } I = 2,5 S \frac{I}{y} \text{ cm}^4$$

where  $h$  = vertical distance, in metres, from the mid-point of length to the top of the tank or half the distance, in metres, from the mid-point of length to the top of the overflow, whichever is the greater. For girders supporting side frames,  $h$  is in no case to be taken as less than the distance from the girder to the upper deck at side, or to a line 1,4d above the keel, whichever is the lesser,

$b$  = distance, in metres, between the centres of the two adjacent spans of stiffeners or frames supported by the girder,

$d$  = moulded draught, in metres,

$S$  = span of girder, in metres, measured between span points as shown in D 130.

Where the relative density (specific gravity),  $\rho$ , of the liquid to be carried exceeds 1,025, the value of  $\frac{I}{y}$  is to be multiplied by the factor:—

$$\frac{\rho}{1,025}$$

**1916** If girders are fitted, they are to form a continuous line of support on bulkheads and ship's side. The thickness of the girder web plate is not to be less than:—

$$t = 9 + 0,008 \left( \frac{d_w}{50} \right)^2 \text{ mm}$$

where  $d_w$  = depth of web, in mm.

They are to be connected at their ends by flanged brackets having the same thickness as the web plate of the thicker girder and a length of arm, measured from the point of the bracket to the edge of the girder, equal to the width of the wider girder. If the bracket terminates on a bulkhead, the length of the arms is to be equal to the width of the girder. The ends of the brackets are to be adequately supported.

TABLE D 19.1

TYPE OF BULKHEAD	PARAMETER	POSITION IN BULKHEAD	NOT TO EXCEED	NOT TO BE LESS THAN
Symmetrical corrugations	$\frac{b}{t_p}$	$\left\{ \begin{array}{l} \text{Top} \\ \text{Bottom} \end{array} \right\}$	70	—
	$\theta$	All	—	40°
Double plate	$\frac{s}{t}$	$\left\{ \begin{array}{l} \text{Top} \\ \text{Bottom} \end{array} \right\}$	75 65	— —
	$\frac{d}{t_w}$	$\left\{ \begin{array}{l} \text{Top} \\ \text{Bottom} \end{array} \right\}$	85 75	— —
	$A_w$	Top	—	$\frac{0,07}{l} \frac{I}{y} \text{ cm}^2$
		Bottom	—	$\frac{0,1}{l} \frac{I}{y} \text{ cm}^2$

where  $\theta$  = angle of web of corrugation to plane of bulkhead (see Fig. D 1.2),

$d$  = depth, in mm, of double plate bulkhead (see Fig. D 18.4),

$s$  = spacing, in mm, of vertical stiffeners of double plate bulkhead,

$A_w$  = section area, in  $\text{cm}^2$ , of webs of double plate bulkhead.



1917 The girders are to be supported by tripping brackets at the toes of the end brackets and elsewhere at every third stiffener or frame. Stiffeners or frames intermediate between these brackets are to be effectively connected to the girders.

#### Topside Tanks

1918 The thickness of the sloping bulkhead plating is to be as required by 1907 but  $h$  is not to be taken as less than that at the half-width of the tank.

In no case is the thickness to be less than required by D 415 for second deck—outside line of openings.

Where the vertical strake of plating under the hatch coaming is greater than 20,5 mm but does not exceed 25,5 mm in thickness, it is to be of Grade B quality steel within 0,4L amidships.

When the thickness exceeds 25,5 mm, Grade D steel is to be used.

*See also D 116 for higher tensile steel.*

1919 Particular attention is to be paid to the structural arrangements within topside tanks.

A transverse should normally be arranged in line with the ends of the main cargo hatchways and in ships exceeding 215 m in length, a fore and aft diaphragm extending vertically from the deck to the sloping plating of the topside tank, may be required at about the half-width of the tank.

#### Decks

1920 The thickness of plating of a deck forming the crown of a tank is to be 1,0 mm greater than that which would be required by 1907, but is not to be less than required by D 4.

1921 The section modulus of beams is not to be less than required by 1908 but is also to satisfy the requirements of D 8.

#### Tunnels and Recesses

1922 The scantlings and arrangements of tunnels, horizontal and longitudinal steps and recesses generally are to be equivalent to the requirements for boundary bulkheads.

#### Ventilators

1923 Ventilators from deep tanks passing through a 'tween deck are to be strong enough to withstand the pressure to which they may be subjected and they are to be made watertight.

#### Welded Connections

1924 Welded connections are to be in accordance with the requirements of Table D 32.1.

#### Special Requirements for Oil Fuel Tanks in Refrigerated Ships

1925 Where the hold above a double bottom tank carrying oil fuel is used for refrigerated cargo, the tank side brackets and floor plates are to be attached to the margin plate by welding, and gussets are to be welded to the margin plate. The connections of hold pillars, including heel doubling plates, also of the floors and intercostal plates under the pillars to the inner bottom, are to be welded. The attachments of manhole covers are not to pass through the inner bottom plating.

1926 For the requirements for protection of oil-tight bulkheads, decks and inner bottom in way of refrigerated holds, *see E 345 and E 346.*

#### Protection and Drainage in Tanks Carrying Oil Fuel or Lubricating Oil

1927 Compartments carrying oil fuel or lubricating oil are to be separated by cofferdams from those carrying feed water, fresh water or vegetable oil. Lubricating oil compartments are to be similarly separated from those carrying fuel oil. Cofferdams are to be suitably ventilated.

For tanks carrying vegetable and similar oils, *see 1932.*

1928 Gutterways are to be arranged at the foot of bulkheads in boiler rooms to ensure that leakage shall have free drainage to the wells or limbers.

1929 Drip trays or gutterways with suitable draining arrangements are to be provided for all tanks which do not form part of the hull structure, at pumps, valves and elsewhere where there is a possibility of leakage.

Drip trays are also to be fitted under oiltight decks, except if these are completely welded, when the drip trays need only be fitted over boilers and exhaust pipes.

1930 If cargo is carried in a compartment adjacent to an oil fuel settling tank which may be heated, the compartment side of the bulkhead or deck is to be insulated or equivalent arrangements provided.

#### Tanks Carrying Vegetable and Similar Oils

1931 The ventilation, drainage and control are to be generally as required for oil fuel tanks.

1932 Deep or peak tanks carrying vegetable or similar oils are to be separated from those carrying oil fuel, lubricating oil or fresh or feed water by a cofferdam.



Cofferdams are not required between oil fuel double bottom tanks and deep tanks above provided the inner bottom plating is not subjected to a head of oil fuel.

**1933** All erection holes in knees, brackets, etc., are to be closed effectively. *See* Table D 32.1, Note 6, regarding welding.

#### Testing

**1934** Tanks are to be tested by a head of water equal to the maximum to which the tank may be subjected, but not less than 2.45 m above the crown of the tank.

Topside tanks are to be tested either by testing each tank in accordance with the above or water testing one tank on each side of the ship and air testing the remainder. The air test is to be in accordance with D 5202. The tanks to be water tested are to be selected by the Surveyor.

When a preservative coating is to be applied to the internal structure of a tank, the water testing may take place after the application of the preservative, provided the structure is carefully examined to ensure that all welding and structural stiffening is completed prior to the application of the coating, and any riveted shell seams are tested with a high pressure hose test on the berth before coating. The hose test of the riveted seams may be carried out from the outside to avoid wetting the tank structure. As an alternative to hose testing, a leak test as described in D 5202 would be accepted.

The cause of any discoloration or disturbance of the coating is to be ascertained and any deficiencies repaired.

The attachment of fittings to oiltight surfaces should be completed before tanks are tested.

#### Loading Certificates

**1935** When a loading certificate is requested, before a cargo of oil is loaded the tank should be tested under pressure and examined for cleanness to ensure that it is in a proper condition to receive the oil cargo.

In special circumstances the Committee will be prepared, with the consent of all interested parties, to consider alternative arrangements in respect of the testing of these tanks.

#### Cross-references

**1936** For side frames in deep tanks, *see* D 7.

For reductions when an approved system of corrosion control is fitted, *see* D 2.

For hatch covers, *see* D 2641.

For air and sounding pipes, *see* D 29.

For pumping and piping arrangements, *see* Chapter E.

### Section 20

#### WATERTIGHT TUNNELS

##### Tunnels

**2001** Where a machinery space is situated with a compartment or compartments between it and the after peak bulkhead, the shafting is to be enclosed in a watertight tunnel large enough to permit proper examination and repair of shafting. A sliding watertight door, capable of being operated locally on both sides of the door, is to be provided at the forward end of the tunnel. *See* D 2113.

Pipe tunnels are to have dimensions adequate for reasonable access.

##### Plating

**2002** The thickness of tunnel plating is to be determined from D 1809. The thickness of plating derived from D 1809 may be reduced by 10 per cent for top plating where it is well curved.

If the top of the tunnel is flat the plating is to be not less than 10 per cent thicker than required by D 1809.

**2003** Under hatchways the top plating is to be increased by 2 mm, unless covered with wood not less than 50 mm in thickness which is to be secured by fastenings which do not penetrate the plating.

Where it is intended to use plywood or other forms of ceiling of an approved type instead of planking, the thickness will be considered in each case.

##### Stiffeners and End Attachments

**2004** The scantlings of stiffeners are to be determined from D 1814 taking  $\omega_1 = 1$  and  $\omega_2 = 1$  in the appropriate formula. The span of the stiffener  $l$  is to be taken as the overall height of the tunnel, measured vertically at the centreline of the tunnel.

Where the tunnel top is flat, scantlings of the top stiffeners are also to satisfy D 8 where appropriate.

The lower end connection to the tank top is to be welded. *See* Table D 32.1.

##### Tunnels in Deep Tanks

**2005** When tunnels form boundaries of deep tanks the requirements of D 19 are to be applied where appropriate.

##### Local Strengthening

**2006** Additional strengthening is to be fitted under the heels of pillars or masts stepped on the tunnel.

The strength of bulkheads in way of watertight doors is to be maintained. *See* D 1811.



**Ventilators**

2007 Tunnel ventilators are to have scantlings suitable for the pressure to which they may be subjected and are to be made watertight.

**Testing**

2008 Tunnels are to be hose tested on completion.

**Passageways**

2009 Where fore and aft underdeck passageways are arranged at the ship's side, the after access thereto is to be by a watertight trunk led to the upper deck. Alternative arrangements to prevent the engine room being flooded in the event of a collision if the passageway doors are left open will be considered.

**Section 21****MACHINERY SPACES****Engine Seatings**

2101 The main engine seating should, in general, be integral with the double bottom structure; this particularly applies to higher power diesel or turbine installations. The tank top in way of the engine foundation should be substantially increased in thickness.

Where the main machinery is supported on built-up seatings, the scantlings of these seatings are to be appropriate to the size of the machinery. Adequate transverse stiffening, in the form of tripping brackets in line with floors, is to be provided. Care must be taken to ensure continuity in strength between the longitudinal girders under the seating and the ship longitudinal girders. See D 920 and D 928.

2102 The plating under the foremost shaft tunnel bearing is to be increased in thickness and is to be scarfed into the heavy plating under the engine bedplate.

**Boiler Bearers**

2103 Boiler bearers are to be of substantial construction and efficiently supported by transverse brackets and longitudinal girders. See D 910 and D 922.

**Clearance between Bulkheads and Boilers**

2104 Bulkheads are to be kept well clear of boilers and uptakes, and sufficient space is to be allowed all around boilers for proper access and ventilation.

2105 Decks or flats and the tops of recesses are, in general, to be not less than 1,2 m clear of the boiler top. Uptakes and flat surfaces of boilers are to be not less than 450 mm and the cylindrical shells of boilers not less than 230 mm from bunker or hold bulkheads.

**Exposed Casings Protecting Machinery Openings**

2106 The scantlings of exposed casings protecting machinery openings, and of access openings where fitted, are to be in accordance with the requirements of D 17.

2107 It is recommended that fixed side scuttles are not fitted in exposed machinery casings but, where they are fitted, hinged steel weathertight covers are to be provided.

Opening side scuttles are not permitted.

2108 Cross ties may be required in way of particularly large deck openings.

**Protected Casings**

2109 Protected machinery casings are to have scantlings not less than:—

Plating in way of cargo spaces,  
thickness  $t = 6,5$  mm

Plating in way of accommodation spaces,  
thickness  $t = 5$  mm

Where the spacing of stiffeners exceeds 760 mm the plating thickness is to be increased at the rate of 0,25 mm per 76 mm increase.

Stiffeners are to have a section modulus not less than:—

$$\frac{I}{y} = 0,008 ls \text{ cm}^3$$

where  $l$  = length of stiffener, in metres,

$s$  = stiffener spacing, in mm.

2110 Where casing side stiffeners carry loads from decks above, or where they are in line with pillars below, they are to be suitably increased.

2111 Where casing sides act as girder webs supporting tiers of decks above, care must be taken when cutting access openings to ensure that web continuity is maintained. Particular attention should be paid to stiffening where supporting funnel and exhaust uptakes in motor vessels.

**Skylights**

2112 Where skylights are fitted to machinery spaces, they are to be constructed in accordance with D 1730.



It is recommended that glass panels are not fitted in skylights. Openings in skylights including fixed glass panels, where fitted, are to be protected by strong steel covers permanently attached and capable of being closed from outside the machinery space from a position which would be readily accessible despite the event of a fire within the machinery space. *See also F 337.*

#### Means of Escape

**2113** In machinery spaces, two means of escape, one of which may be a watertight door, shall be provided from each engine room, shaft tunnel and boiler room. In machinery spaces where no watertight door is available, the two means of escape shall be formed by two sets of steel ladders as widely separated as possible leading to doors in the casing similarly separated and from which access is provided to the lifeboat embarkation deck. In the case of ships of less than 2000 tons gross, this requirement may be dispensed with, due regard being paid to the width and the disposition of the casing.

#### Communications

**2114** Two means of communication are to be fitted between the bridge and the engine room.

#### Aluminium Alloy

**2115** When aluminium alloy is used in the construction of the boundaries of the machinery space or in the casings or pillars, suitable insulation is to be fitted so that the structure remains effective in the presence of intense heat. The extent of the insulation is to be governed by the fire risk on either side of the boundary.

#### Additional Strengthening in Machinery Space

**2116** Additional transverse strengthening is to be provided by means of web frames (*see D 717*) and strong beams, with suitable pillaring or other arrangements.

#### Machinery Spaces at Aft End of Ship

**2117** Where applicable, D 55 is to be used for the construction of machinery spaces in this position.

#### Cross-references

**2118** For passenger ships, *see F 807, F 812 and F 814.*

For gutterway and drip trays, *see D 1928 and D 1929.*

### Section 22

#### RUDDERS

##### Materials

**2201** Steel castings are to comply with the requirements of P 5.

**2202** Forgings are to comply with the requirements of P 6.

##### Rudder Stock

**2203** The diameter of the rudder stock,  $d_s$ , at and below the lowest bearing is not to be less than given by the following formula. For the minimum diameter of stock above the lowest bearing,  $a$  in the formula is to be taken equal to zero.

For spade type rudders, as shown in Fig. D 22.1 (b), the minimum diameter of the stock above the lowest bearing is to be not less than  $d_s$  calculated with  $a$  equal to zero or 70 per cent of the Rule diameter of the stock at and below the lowest bearing, whichever is the greater. When the Rule diameter at the lowest bearing exceeds 600 mm the diameter of the stock at the upper bearing will be considered in each case.

(a) Ahead condition:—

$$d_s = 83,3 k \left( \sqrt[3]{(V+3)^2 \sqrt{A^2 S^2 + a^2}} \right) \text{ mm}$$

where  $A$  = rudder area, in  $\text{m}^2$ ,

$S$  = horizontal distance, in metres, from the centreline of the rudder pintles, or axle, to the centre of pressure of the rudder area, but is not to be less than 12 per cent of the breadth of the rudder.

For non-rectangular rudders the minimum value is to be taken as:—

$$\frac{0,12 \times \text{Area in } \text{m}^2}{\text{Depth on centreline of stock, in metres}}$$

For rectangular rudders, the centre of pressure may be taken at one-third of the breadth of the rudder from its leading edge.

For the astern condition, *see (b).*

$V$  = the maximum service speed, in knots, with the ship in the loaded condition,

$k$  = 0,248 for rudders working in a propeller slipstream and 0,235 for rudders situated on the centreline of twin screw ships.

For the astern condition, *see (b).*

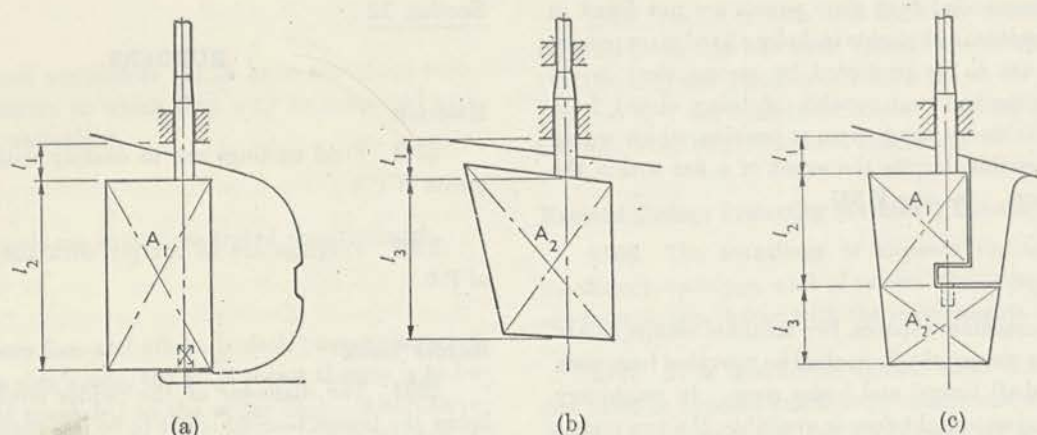


FIG. D 22.1

$a$  = a value depending upon the rudder support arrangement and is equal to zero when two or more pintles are fitted.

When one or no pintles are fitted, as shown in Fig. D 22.1:—

$$a = A_1 \left( \frac{l_1}{1.5} + \frac{l_2}{6} \right) - A_2 \left( l_1 + \frac{l_3}{2} \right)$$

$A_1$  and  $A_2$  are areas measured in  $m^2$ ,  $l_1$ ,  $l_2$  and  $l_3$  are measured at the centreline of the rudder stock, in metres. Values for  $l_3$  and  $l_2$  not shown in Fig. D 22.1 (a) and (b) respectively are to be taken as zero.

Where in semi-spade rudders the pintle is housed above the rudder horn gudgeon, and not below as shown in Fig. D 22.1(c),  $l_2$  and  $l_3$  are to be measured to the top of the gudgeon.

(b) Astern condition:—

The rudder stock diameter is to be calculated for the astern condition using the formula given in (a), where:—

$V$  = astern speed, in knots. Unless special service conditions apply, the ship astern speed should be taken as half the speed ahead,

$$k = 0.185$$

The centre of pressure of the rudder is to be taken at  $0.25 \times$  the breadth of the rudder from the aft edge.

**2204** The diameter of the rudder stock in way of the rudder is to be maintained to a point as far as practicable above the top of the lowest bearing. This diameter is then to be tapered to the diameter required in way of the tiller. The slope of the taper is to be as gradual as practicable but is to be taken not greater than 1 in 3 on the diameter.

Particular care is to be taken to avoid the formation of a notch at the upper end of the taper (see Fig. D 22.2).

Sudden changes of section or sharp corners in way of the rudder coupling, collars for jumping rings, and shoulders for rudder carriers, are to be avoided. Jumping collars are not to be welded to the rudderstock.

Keyways in the rudderstock are to have rounded ends and the corners are to be provided with fillets.

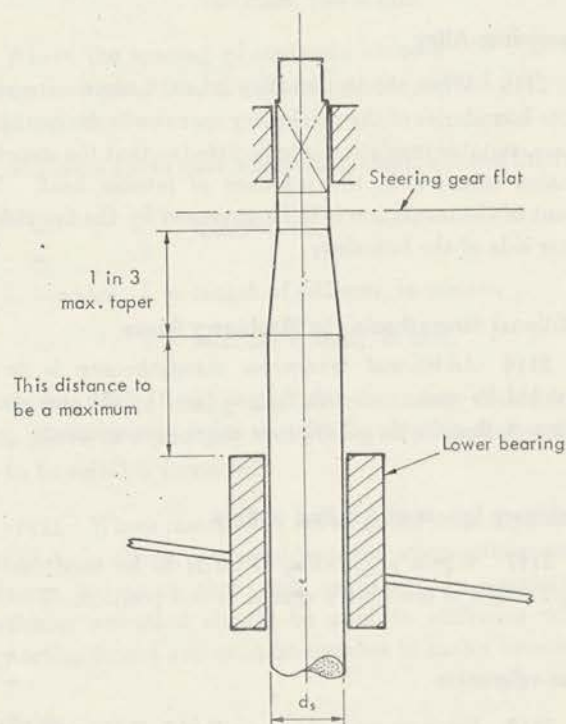


FIG. D 22.2



**Rudder Couplings**

**2205** Bolts in horizontal couplings are to have a diameter not less than:—

$$d_b = \frac{0,65 d_s}{\sqrt{n}} \text{ mm}$$

and the first moment of area,  $M$ , of the bolts about the centre of the coupling is not to be less than:—

$$M = \frac{0,71 n d_s d_b^2}{1000} \text{ cm}^3$$

where  $d_b$  = bolt diameter, in mm,

$d_s$  = rudder stock diameter obtained from 2203, in mm,

$n$  = number of bolts but not to be less than six.

The thickness of the coupling flanges is not to be less than  $d_b$  mm.

**2206** Vertical couplings are to have not less than eight securing bolts each having a diameter not less than:—

$$d_b = \frac{0,81 d_s}{\sqrt{n}} \text{ mm}$$

and the first moment of area,  $M$ , of the bolts about a vertical axis through the centre of the coupling is not to be less than:—

$$M = \frac{0,43 d_s^3}{1000} \text{ cm}^3$$

where  $d_b$ ,  $d_s$  and  $n$  are as specified in 2205.

**2207** The width of material in coupling flanges outside the boltholes is not to be less than two-thirds of the Rule bolt diameter.

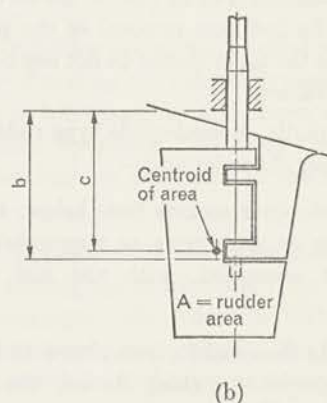
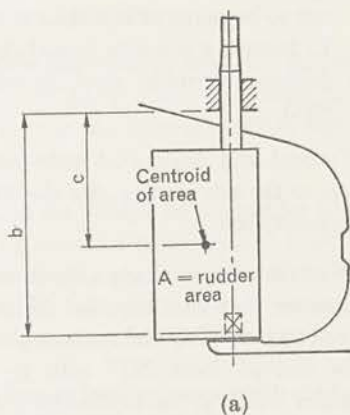


FIG. D 22.3

**2208** Coupling bolts are to be fitted and suitable arrangements are to be made to lock the nuts.

**Rudder Pintles**

**2209** Rudder pintles are to have a diameter not less than:—

$$d_p = 31 + 4,17 V \sqrt{A_p} \text{ mm}$$

where  $d_p$  = pintle diameter (measured outside liner, if fitted),

$V$  = ship speed but is not to be taken as less than 10 knots,

$A$  = total rudder area, in  $m^2$ ,

$A_p$  = rudder area supported by the pintle, in  $m^2$ . For rudders with two or more pintles (except semi-spade rudders),  $A_p$  is to be taken as the total area of the rudder divided by the number of pintles.

For rudders of the types shown in Fig. D 22.3,  $A_p$  is to be calculated as follows:—

On single pintle rudders (Fig. D 22.3(a)),

$$A_p = \frac{A \times c}{b}$$

On semi-spade rudders (Fig. D 22.3(b)),

$$\text{For lower pintle, } A_p = \frac{A \times c}{b},$$

but need not be taken greater than  $A$ .

$$\text{For upper pintle, } A_p = A \left(1 - \frac{c}{b}\right),$$

but is not to be less than  $0,35A$ .

Where the lower pintle is housed above the rudder horn gudgeon, and not below as shown in Fig. D 22.3(b),  $b$  is to be measured to the top of the gudgeon.

**2210** The bearing length of pintles in their gudgeons and housings is, in general, to be 20 per cent greater than the diameter of the pindle obtained from 2209, but for very large pintles may be less, provided that the bearing pressure is not greater than:—

Metal bearings ..... 6,86 N/mm<sup>2</sup> (70 kgf/cm<sup>2</sup>)

Lignum vitæ or  
synthetic bearings..... 5,50 N/mm<sup>2</sup> (56 kgf/cm<sup>2</sup>)

based on the projected area (i.e. length × diameter).

The force acting on the bearing may be taken as

$$F = \frac{A_p (V + 3)^2}{10,2} \text{ kN}$$

$$\left( F = \frac{A_p (V + 3)^2}{100} \text{ tonne-f} \right)$$

where  $A_p$  is as derived from 2209.

In no case is the bearing length to be less than the pindle diameter. The width of material in the gudgeons (measured outside the bushing if fitted) is not to be less than 50 per cent of the Rule pindle diameter, but need not normally exceed 125 mm.

AMENDED NOTICE No. 2

**2211** Pintles are to have a taper not greater than:—

1 in 6 on diameter for keyed and other manually assembled pintles of 200 mm or less in diameter,

1 in 9 on diameter for keyed and other manually assembled pintles of 400 mm and over, (intermediate sizes by interpolation),

1 in 12 on diameter for hydraulically assembled pintles using dry fit methods,

1 in 15 on diameter for hydraulically assembled pintles using oil injection methods of fitting.

Particular attention is to be paid to the fit of the taper into its socket. To facilitate removal of the pintles, it is recommended that the taper should be not less than half the above maximum values.

The bottom pindle on semi-spade type rudders and all pintles over 500 mm diameter are:—

(a) if inserted into their sockets from below: to be keyed to the rudder or sternframe as appropriate or to be hydraulically assembled, with the nut adequately locked, or

(b) if inserted into their sockets from above: to be provided with an appropriate locking device, the nut being adequately secured.

See D 1218 for axle type rudder bearings.

**2212** The pindle clearances with metal bearings should be not less than  $\frac{d_p}{1000} + 1,0$  mm on the diameter and with synthetic bushes should be not less than  $\frac{d_p}{500} + 1,0$  mm.

The clearance with synthetic bushes, however, should be not less than 1,5 mm irrespective of pindle diameter.

Note should be taken of manufacturers' recommended clearances, particularly when bush material requires pre-soaking.

**2213** Synthetic rudder bearing materials are to be of a type approved by the Society. When this type of lining material is used, an adequate supply of water to the bearing is to be provided.

**2214** Where it is proposed to use stainless steel for liners or bearings the chemical composition is to be submitted for approval.

**2215** The distance between the lowest rudder stock bearing and the upper pindle should be as short as possible.

**2216** Where liners are fitted to pintles they are to be shrunk on or otherwise efficiently secured. When liners are to be shrunk on, the shrinkage allowance is to be indicated on the plans.

#### Rudder Plating

**2217** Rudder side plating in double plated rudders is to have a thickness not less than:—

$$t = \frac{b_1 + 610}{1000} \left( 4 - \frac{b_1}{s} \right) (1,45 + 0,1 \sqrt{d_s}) \text{ mm}$$

where  $b_1$  = spacing, in mm, of the horizontal webs, and is not to exceed 1220 mm,

$s$  = spacing, in mm, of the vertical webs and is not to be taken as less than  $b_1$  in the formula.

In general,  $s$  is not to exceed  $2b_1$  in any panel.

$d_s$  = diameter of rudder stock, in mm, required by 2203.

**2218** Vertical and horizontal webs are to have the same thickness as the side plating. See also 2220 for vertical webs forming mainpiece.

**2219** Nose plates are to have a thickness not less than 25 per cent greater than that required for side plating but need not exceed 22 mm. Top and bottom plates are to have the thickness derived from 2217 with  $b_1$  taken as the maximum rudder width at top or bottom but not less than 900 mm. In way of rudder couplings and heel pintles the plating thickness is to be suitably increased.



**Mainpiece**

2220 Fabricated mainpieces may be of rectangular or tubular section. The breadth and width of rectangular mainpieces are not to be less than the diameter required by 2203. The thickness of the side plating and vertical webs that form a rectangular mainpiece are not to be less than:—

$$t_m = 8,5 + 0,56 \sqrt{d_s} \text{ mm}$$

The increased side plating is to have a minimum fore and aft extent of 20 per cent of the rudder breadth and is to be attached to the two vertical webs forming the mainpiece.

Tubular mainpieces are to have an inside diameter not less than required by 2203, and a thickness not less than  $t_m$  mm as given in the previous sub-paragraph. When tubular mainpieces are fitted, the rudder side plating in way may be as required by 2217

**General**

2221 Connection of rudder side plating to vertical and horizontal webs, where internal access for welding is not practicable, is to be by means of slot welds on to flat bars on the webs.

The slots are to have a minimum length of 75 mm and, in general, a minimum width of twice the side plating thickness. The ends of the slots are to be rounded.

The space between the slots is not to exceed 150 mm, and welding is to be based on a weld factor of 0,44.

2222 Internal surfaces of double plate rudders are to be efficiently coated and means for draining the rudder are to be provided.

2223 Where it is intended to fill the rudder with plastic foam, details of the foam are to be submitted.

2224 Suitable arrangements are to be provided to prevent the rudder from lifting.

2225 Where bow rudders are fitted for use when going astern, they are to have a locking device to ensure that the rudder is kept in the central position when the ship is going ahead.

2226 When the weight of the rudder is supported by a carrier bearing attached to the rudder head the structure in way is to be adequately strengthened for that purpose. The plating under all rudder head bearings or rudder carriers is to be increased in thickness.

2227 Adequate hand or access holes are to be arranged in the rudder plating in way of pintles as required, and the rudder is to be reinforced in way of these openings.

**Testing**

2228 Double plated rudders are to be tested by a head of water of 2,45 m, or by an air pressure of approximately 0,021 N/mm<sup>2</sup> (0,21 kgf/cm<sup>2</sup>). When a water test is used the rudder should normally be tested while laid on its side, especially if the rudder is very large. When air testing is used, the arrangements should be such as to ensure that a pressure in excess of 0,03 N/mm<sup>2</sup> (0,30 kgf/cm<sup>2</sup>) cannot be applied, inadvertently or otherwise.

**Cross-reference**

2229 For strengthening for navigation in ice, *see* D 24.

**Section 23****STEERING GEAR****Symbols****2301**

$d_s$  = diameter of rudder stock, in mm, at the tiller head, as obtained from D 2203,

$a$  = distance from the point of application of the load on the tiller to the centre of the rudder stock, in mm,

$b$  = distance between the section of the tiller arm under consideration and the centre of the rudder stock, in mm.

NOTE.  $a$  and  $b$  are to be measured with zero rudder angle.

$n$  = total number of bolts in the tiller coupling.

NOTE.  $n$  in general is not to be taken greater than six.

$Y$  = minimum yield stress or 0,5 per cent proof stress of the tiller bolt material, in N/mm<sup>2</sup> (kgf/mm<sup>2</sup>).

**General**

2302 All ships are to be provided with two independent means of moving the rudder. In passenger ships and in cargo ships of 500 tons gross and above, one of the gears is to be operated by power. All gears are to be fitted and tested under working conditions to the satisfaction of the Surveyors.

2303 The power operated main steering gear is to be capable of putting the rudder over from 35 degrees on one side to 35 degrees on the other side with the ship running ahead at maximum service speed. The time taken to put the rudder over from 35 degrees on either side to 30 degrees on the other side is not to exceed 28 seconds at maximum service speed.



The gear is also to be designed in relation to the maximum astern speed. See D 2203.

**2304** The auxiliary gear is to be of adequate strength and sufficient to steer the ship at navigable speed and is to be capable of being brought speedily into action in an emergency.

**2305** In cargo ships, a power operated auxiliary gear is to be fitted where the Rule diameter of the rudder stock at the tiller, corresponding to a speed of 10 knots, is 250 mm and above. Where main steering gear power units and their connections are fitted in duplicate and the duplicate units acting together satisfy the requirements of 2303, and each power unit separately satisfies the requirements of 2304, an auxiliary gear will not be required.

**2306** In passenger ships, the auxiliary gear is to be power operated if the Rule diameter of rudder stock at the tiller exceeds 230 mm. When main steering gear power units and their connections are fitted in duplicate and each power unit separately is capable of satisfying the requirements of 2303, an auxiliary gear will not be required.

**2307** In passenger ships, where the Rule diameter of the rudder stock at the tiller exceeds 230 mm, an alternative steering position remote from the main steering position is to be provided. The steering control systems from the main and alternative steering stations are to be arranged so that failure of either system would not result in inability to steer the ship by means of the other system.

Means are to be provided to enable orders to be transmitted from the bridge to the alternative steering station.

**2308** The exact position of the rudder, if power operated, shall be indicated at the main steering station.

**2309** The after steering wheel and gear in ocean-going ships are to be adequately protected or situated in such a position that protection can be dispensed with.

**2310** The steering gear is to be secured to the seating by fitted bolts and suitable chocking arrangements are to be provided.

#### Tillers and Quadrants

**2311** Tillers and quadrants are to be shrunk on, hydraulically assembled or bolted to the rudder stock. The shrinkage allowance is to be between 1/550 and 1/700 of the diameter of the rudder stock in way, except when a key is fitted in which case the allowance should not exceed 1/1100.

Where hydraulic methods are used for assembly, the interference fit between the tiller and the rudder stock is to be as for the shrinkage allowance indicated above. The

rudder stock is to have a taper not exceeding 1:12 on the diameter for dry fits and not exceeding 1:15 on the diameter when oil injection methods are used.

Where the tiller and quadrant are bolted, a shim is to be fitted between the two halves of the tiller prior to its being machined to take the rudder stock, and removed prior to fitting to rudder stock. The thickness of the shim is to be not less than:—

- (a) if  $n = 4$ ,  $1/700$  of the diameter of the rudder stock in way,
- (b) if  $n = 6$ ,  $1/830$  of the diameter of the rudder stock in way.

Where the tiller and quadrant are bolted, or where a shrinkage or interference fit less than given above is used, a key having an effective sectional area in shear not less than  $0,25 d_s^2 \text{ mm}^2$  is to be fitted. The thickness of the key should not be less than  $\frac{d_s}{6} \text{ mm}$ .

The keyways should extend over the full depth of the tiller and are to have rounded ends.

**2312** The section modulus of the tiller arm at any point within its length taken about a vertical axis is not to be less than the greater of the following:—

For a single arm tiller

$$(a) \quad \frac{I}{y} = \frac{0,15 d_s^3 (a-b)}{1000a} \text{ cm}^3$$

$$(b) \quad \frac{I}{y} = \frac{0,06 d_s^3 (a-0,9 d_s)}{1000a} \text{ cm}^3$$

Where more than one arm is fitted, the combined modulus of the arms is not to be less than as required above.

For solid tillers the breadth to depth ratio is not to be more than 2.

**2313** The depth of the boss is not to be less than the diameter of the rudder stock  $d_s$ . The thickness of the boss in way of the tiller is not to be less than  $0,4 d_s$ .

**2314** The diameter of bolts in bolted tillers or quadrants is not to be less than:—

$$d_b = \frac{0,60 d_s}{\sqrt{n}} \text{ mm}$$

**2315** Where the diameter of the rudder stock is greater than 400 mm, higher tensile steel bolts are to be used for bolted tillers. A predetermined setting up load equivalent to a stress of approximately  $0,7Y$  should be applied to each bolt when the tiller is assembled.



The yield and ultimate tensile stress of the bolt material are to be stated on plans submitted for approval, together with full details of the methods to be adopted to obtain the required stress. Where patent nuts or systems are used, the manufacturers' instructions for assembly should be adhered to.

Alternatively, a lower stress in the bolts may be accepted providing two keys are fitted each having dimensions as specified in 2311.

**2316** With bolted tillers the distance from the centre of the rudder stock to the centre of the bolts should generally be equal to  $d_s \left(1,0 + \frac{0,3}{\sqrt{n}}\right)$  mm

**2317** The thickness of the flange in each half of the bolted tiller should not be less than  $\frac{0,66 d_s}{\sqrt{n}}$  mm

#### Locking or Brake Gear

**2318** An efficient locking or brake arrangement is to be fitted to all gears to keep the rudder steady when necessary.

In bow rudders where a vertical locking pin is operated from the deck above, positive means are to be provided to ensure that the pin can be lowered only when the rudder is exactly central. In addition, an indicator is to be fitted at the deck to show when the rudder is exactly central.

#### Rudder Stops

**2319** Suitable stopping arrangements are to be provided for the rudder. Cut-outs on the steering engine are to be arranged to operate at a smaller angle of helm than those for the rudder.

#### Cross-reference

**2320** For strengthening for navigation in ice, *see* D 24.

### Section 24

**NOTE.** The following Rules for navigation in ice are intended for ships operating in areas with first year ice only and are not designed for multi-year ice conditions.

Ships intending to navigate in Canadian Arctic zones must comply with the Canadian Arctic Shipping Pollution Prevention Regulations of October 1972, in respect of which the Society is authorized to issue Arctic Pollution Prevention Certificates.

### STRENGTHENING FOR NAVIGATION IN ICE (GENERAL SERVICE)

Where the notation "Ice Class 1\*, 1, 2 or 3" as specified in B 129 (a) is desired, the following requirements are to be complied with, so far as these are applicable.

(For northern Baltic service, *see* D 24A)

#### Symbols

- 2401**  $L$  = length of ship, in metres,  
 $L_1$  = length of ship, in metres, but need not be taken as greater than 215 m,  
 $B$  = moulded breadth, in metres,  
 $s$  = frame spacing, in mm,  
 $s_b$  = basic frame spacing, in mm,  
 i.e. (a) aft of  $0,2L$  from fore perpendicular to the after peak bulkhead:—  

$$\frac{L_1}{0,6} + 510 \text{ mm}$$
 (b) forward of  $0,2L$  from fore perpendicular to the fore peak bulkhead:—  
 as required by D 705, but is not to exceed the spacing required by (a) above,  
 (c) in peaks and cruiser sterns:—  
 as required by D 706,  
 $t_b$  = basic ice shell plating thickness, =  

$$\left(5 + \frac{L}{13,65}\right) \sqrt{\frac{s}{s_b}} \text{ mm}$$
 $H$  = maximum shaft power, *see* H 104, H 105 and H 502.

**2402** The vertical extent of ice strengthening is related to Light and Load waterlines which are to be determined as follows:—

Light waterline is the lowest waterline, taking account of trim, at any point along the length of the ship corresponding to either of the following conditions:

- The lightest load condition in which the ship may be expected to be at sea in ice conditions.
- The ballast condition.

Load waterline is that corresponding to the winter load line. (For ships trading in the Baltic at the summer load line, the ice strengthening is to be based on this load line. In these cases a suitable notation will be made in the *Register Book*.)

The position of maximum breadth on the winter load waterline is to be indicated on the plans.



## FRAMING

## Class 1\*

**2403** The frame spacing is not, in general, to exceed 610 mm between the forward perpendicular and 0,25L forward of amidships, and 800 mm over the remainder of the length to the after peak bulkhead.

**2404** Intermediate frames are to be fitted over the full length of the ship. The strength of these frames is to be the same as that of the adjacent Rule main or 'tween deck frames.

In way of deep tanks the section modulus of intermediate frames may be that of the main frames before the increase required by D 719 is applied.

In the panting region clear of deep tanks the intermediate frames may have a section modulus as derived from D 707 (2) but ignoring the factor  $f$ .

The intermediate frames are to extend from the upper deck, or from the second deck provided this is at least 750 mm above the load waterline, to below the level of the top floors or to a point just above the tank top where this runs horizontally to the ship's side, and need not be connected at their ends. Where the second deck is above the load waterline but less than 750 mm above, the intermediate frames may terminate at a stringer situated not less than 1,2 m above the load waterline.

In the fore and aft peaks the main and intermediate frames are to have the same modulus as an amidship frame determined from D 707 (1) with a frame spacing equal to  $\frac{L_1}{0,6} + 510$  mm, or a modulus equal to twice that of the normal peak frames, whichever is the greater.

Where the frames terminate at the 2nd deck, and long or broad hatchways are fitted in this deck, the plating in way of the hatchways is to be suitably strengthened by fitting web frames or strong beams to give adequate support to the framing.

## Class 1

**2405** Intermediate frames are to be fitted over the full length of the ship. The strength of these frames is to be the same as that of the adjacent Rule main or 'tween deck frames, unless stringers are fitted in accordance with 2429 when the intermediate frames may be 75 per cent of the adjacent Rule frames.

In way of deep tanks the section modulus of intermediate frames may be that of the main frames before the increase required by D 719 is applied.

In the panting region clear of deep tanks the intermediate frames may have a section modulus as derived from D 707 (2) but ignoring the factor  $f$ .

The intermediate frames are to extend from 915 mm below the light waterline to 750 mm above the load waterline. They are to be connected at their ends to the adjacent frames by a horizontal member having the same scantlings as these frames, or equivalent arrangements are to be provided. Alternatively, they are to be carried down to within 255 mm of the margin plate or, where the ship has no double bottom, to a point below the top floors. If the frames are so extended they need not be attached at the lower end.

In the fore and aft peaks the main and intermediate frames are to have the same modulus as an amidship frame determined from D 707 (1) with a frame spacing equal to  $\frac{L_1}{0,6} + 510$  mm, or a modulus equal to twice that of the normal peak frames, whichever is the greater.

## Class 2

**2406** Intermediate frames are to be as required by 2405 except that they need only be fitted in the region from the forward perpendicular aft for a length equal to the distance from the forward perpendicular to the point where the load waterline reaches its greatest breadth plus 10 per cent of that distance.

## Class 3

**2407** For the longitudinal extent given in 2406 intermediate frames are to be fitted abaft the forward perpendicular. They are to extend from 915 mm below the light waterline to 750 mm above the load waterline, and need not be connected at their ends.

The intermediate frames forward of the collision bulkhead should have a modulus equal to 50 per cent of the Rule peak frames, and those aft of the collision bulkhead should have a modulus equal to 80 per cent of the adjacent Rule frames unless stringers are fitted in accordance with 2431. In this case the intermediate frames aft of the collision bulkhead should have a modulus equal to 75 per cent of the Rule peak frames, but in 'tween decks need not exceed the adjacent frame.

## General

**2408** For Ice Classes 1\*, 1 and 2, frames are not to be scalloped, except at the seams in the shell plating, over the area defined in 2410.



**2409** Attention is to be paid to the minimum thickness of frames and other stiffening members. In general, this should not be less than one-half that of the attached hull plating.

Where stringers are not fitted, brackets are to be arranged to prevent the frames from tripping.

### SHELL PLATING

#### Class 1\*

**2410** From the forward perpendicular aft for a length equal to the distance from the forward perpendicular to the point where the load waterline reaches its greatest breadth plus 10 per cent of that distance, and extending vertically from 610 mm below the light waterline to 750 mm above the load waterline, the thickness of the shell plating is not to be less than  $1,8 t_b$  mm.

**2411** From this position to  $0,25L$  aft of amidships and over the same vertical extent, the thickness of shell plating is not to be less than  $1,4 t_b$  mm.

If the parallel middle portion on the load waterline extends further aft than  $0,25L$  aft of amidships, the shell plating over this parallel middle portion is also not to be less than  $1,4 t_b$  mm.

**2412** For the remainder of the length and over the same vertical extent, the thickness of shell plating is not to be less than  $1,25 t_b$  mm.

**2413** The side and bottom shell plating below this belt from the stem to a position five frame spaces abaft the point where the bow profile departs from the level keel line is not to be less than  $1,8 t_b$  mm.

**2414** Where the shaft power,  $H$ , exceeds  $1,66 (L \times B)$  kW ( $2,26 (L \times B)$  shp) the shell plating for the longitudinal extent given in 2410 is to be increased by a further 1 mm for each 370 kW (500 shp) excess over the above calculated shaft power. (The shaft power, kW (shp), is to be indicated on the plan on which the shell plating is submitted for approval.)

**2415** The total plate thickness, including any increase required by the above paragraphs, is not to be less than 14 mm and need not exceed 32 mm. Changes in thickness are to take place gradually.

#### Class 1

**2416** For the longitudinal and vertical extent given in 2410 the thickness of the shell plating is not to be less than  $1,5 t_b$  mm.

**2417** For the remainder of the length and over the same vertical extent the thickness of shell plating is not to be less than  $1,25 t_b$  mm.

**2418** The increased thickness need not exceed 25,5 mm, but is not to be less than 12,5 mm. Changes in thickness are to take place gradually.

#### Class 2

**2419** For the longitudinal and vertical extent given in 2410 the thickness of the shell plating is not to be less than  $1,5 t_b$  mm.

**2420** For the remainder of the length and over the same vertical extent the thickness of shell plating is not to be less than  $1,15 t_b$  mm.

**2421** The increased thickness need not exceed 25,5 mm, but is not to be less than 12,5 mm. Changes in thickness are to take place gradually.

#### Class 3

**2422** For the vertical extent given in 2410 and from the forward perpendicular to the point where the load waterline reaches its greatest breadth the thickness of the shell plating is not to be less than  $1,25 t_b$  mm.

**2423** For the remainder of the length, the thickness is to be normal Rule.

**2424** The increased thickness need not exceed 25,5 mm, but is not to be less than 12,5 mm. Changes in thickness are to take place gradually.

### STRINGERS

#### Class 1\*

**2425** Forward of the collision bulkhead the tiers of beams and stringers required by D 11 are to be spaced not more than 1,3 m apart.

**2426** Abaft the collision bulkhead the stringer next below the load waterline is to be extended over the full length of the ship, unless a deck is situated not more than 1,2 m below the load waterline, and the main and intermediate frames are to be attached thereto.

The stringers immediately above and below this stringer are also to be extended over the full length of the ship, but may be intercostal and of the same scantlings as the frames in way.

**2427** Where the light waterline lies well above the margin, a stringer may be required in the vicinity of the light waterline and over the full length of the ship.



**2428** In single deck ships a stringer is to be arranged in the vicinity of the load waterline, over the full length of the ship.

#### Class 1 and Class 2

**2429** The following requirements apply only when the intermediate frames are made 75 per cent of the adjacent Rule main or 'tween deck frames. *See* 2405.

Abaft the collision bulkhead, stringers of the scantlings given in D 11 are to be fitted 2 m apart for the longitudinal extent given in 2410.

**2430** The stringer next below the load waterline is to be extended over the full length of the ship unless a deck is situated not more than 600 mm below the load waterline, for Ice Class 1 only.

#### Class 3

**2431** When the intermediate frames are made 75 per cent of the Rule peak frames (*see* 2407), stringers of the scantlings given in D 11 are to be fitted 2 m apart abaft the collision bulkhead for the longitudinal extent given in 2410.

#### General

**2432** Attention is to be paid to the minimum thickness of stringers. In general, this should be not less than one-half that of the attached hull plating.

### RUDDER AND STEERING ARRANGEMENTS

**2433** The diameters of the rudder head and pintles are to be increased above that required by D 22 by:—

- Class 1\* — 30 per cent,
- Class 1 — 25 per cent,
- Class 2 — 12,5 per cent,
- Class 3 — 7,5 per cent.

**2434** The side plating and webs of double plate rudders are to be increased above that required by D 22 by:—

- Class 1\* — 50 per cent,
- Class 1 — 50 per cent,
- Class 2 — 25 per cent,
- Class 3 — 10 per cent.

**2435** The gudgeons, remaining rudder items and couplings are to be based on the increased rudder head or pintle and the steering gear is to be suitably protected against, or designed to withstand, the increased loading.

**2436** The rudder head is to be protected by an ice knife, a suitable stern, or other equivalent arrangements—Ice Classes 1\* and 1 only.

### STERNFRAME

**2437** The strength of the rudder horn, rudder post and solepiece and the diameter of the rudder axle (if fitted) are to be increased above the Rule requirements by:—

- Class 1\* — 30 per cent,
- Class 1 — 25 per cent,
- Class 2 — 15 per cent,
- Class 3 — 7,5 per cent.

### STEM

#### Class 1\*

**2438** The bow should be of a form specially designed for navigation in ice.

A solid stem of forged, rolled or cast steel is to be fitted up to 750 mm above the load waterline.

#### General

**2439** The sectional area of a solid stem bar is to be greater than Rule requirements by:—

- Class 1\* — 30 per cent,
- Class 1 — 25 per cent,
- Class 2 — 15 per cent,
- Class 3 — 10 per cent.

The connections of the shell plating to the stem bar are to be flush.

**2440** Where a plate stem is fitted, the thickness of the plates below a position 750 mm above the load waterline is not to be less than:—

- Class 1\* —  $1,8 t_b$
- Class 1 —  $1,65 t_b$
- Class 2 —  $1,65 t_b$
- Class 3 —  $1,5 t_b$

but need not exceed 25,5 mm.

$t_b$  is to be determined using  $s = \frac{L_1}{0,6} + 510 \text{ mm}$

The thickness may be tapered to that of the normal plate stem (*see* D 1205) at the upper deck. Plates which require to be furnaced are to have these thicknesses when finished.

**2441** Below the load waterline, plate stems should be reinforced by a centreline web—Ice Classes 1\* and 1 only—and by horizontal webs. The horizontal webs are to be spaced not more than 700 mm for Class 1\* and 915 mm for other classes.



## GENERAL

## Cross-reference

2442 For machinery requirements, see H 5.

## Section 24A

### STRENGTHENING FOR NAVIGATION IN ICE (NORTHERN BALTIC SERVICE)

When ice class notations as specified in B 129(b) are desired, the ship is to comply with the following requirements which are generally identical with those for the corresponding notations in Annex I of the *Finnish-Swedish Ice Class Rules 1971*. In no case, however, should scantlings be less than those required by the Rules for ordinary sea-going service.

It should be noted that not even ships built to Ice Class IA Super can withstand heavy ice jamming. Also that small ships will be unable to navigate in as severe ice conditions as larger ships having the same ice class, because of their weaker hull and less engine power.

## Definitions

2460 The "ice belt" is that part of the shell plating which has to be reinforced.

The load waterline, LWL, is that corresponding to the winter load line. For ships trading in the Baltic at the summer load line, the ice strengthening is to be based on this load line.

The ballast waterline, BWL, is to be determined in such a way that the propeller, if possible, is wholly submerged. The corresponding forward draught is to be calculated, taking into account a normal amount of fuel and a suitable amount of water ballast. A relatively narrow ice belt will be approved if ballasting arrangements are satisfactory. The load and ballast waterlines are to be indicated on the shell expansion plan.

The displacement,  $V$ , is that related to the summer load line assigned, in tonnes. Relative density (specific gravity of water = 1.0.)

The shaft power,  $H$ , in kW (shp), is the maximum shaft power. See H 104, H 105 and H 522.

## Assumed Ice Pressures

2461 Scantlings of frames and plating are determined by formulæ based on the pressure between the ship's hull and the ice. As the pressure is higher forward than amid-

ships and aft, the ice belt of the ship has been divided into three regions as follows:—

FORWARD: From the stem to a line parallel to and 0,04L aft of the border line of the flat side of hull forward.

MIDSHIP: From the above defined line to a line parallel to and 0,04L aft of the border line of the flat side of hull aft.

AFT: From the aft boundary of the midship region defined above to the stern.

The above regions are to be indicated on the shell expansion plan.

( $L$  = length between perpendiculars, in metres.)

For the four ice classes the pressure,  $p$ , in the three regions on the ice belt is as follows:—

## FORWARD

IA Super:  $p = 0,63 + 0,072k$  max. 1,62 N/mm<sup>2</sup>

( $p = 6,40 + 0,730k$  max. 16,5 kgf/cm<sup>2</sup>)

IA:  $p = 0,57 + 0,063k$  max. 1,47 N/mm<sup>2</sup>

( $p = 5,80 + 0,640k$  max. 15,0 kgf/cm<sup>2</sup>)

IB:  $p = 0,51 + 0,054k$  max. 1,32 N/mm<sup>2</sup>

( $p = 5,20 + 0,550k$  max. 13,5 kgf/cm<sup>2</sup>)

IC:  $p = 0,45 + 0,045k$  max. 1,18 N/mm<sup>2</sup>

( $p = 4,60 + 0,460k$  max. 12,0 kgf/cm<sup>2</sup>)

## MIDSHIP

IA Super:  $p = 0,56 + 0,021k$  max. 0,84 N/mm<sup>2</sup>

( $p = 5,70 + 0,210k$  max. 8,6 kgf/cm<sup>2</sup>)

IA:  $p = 0,45 + 0,014k$  max. 0,68 N/mm<sup>2</sup>

( $p = 4,60 + 0,140k$  max. 6,9 kgf/cm<sup>2</sup>)

IB:  $p = 0,34 + 0,007k$  max. 0,45 N/mm<sup>2</sup>

( $p = 3,50 + 0,070k$  max. 4,6 kgf/cm<sup>2</sup>)

IC:  $p = 0,235$  N/mm<sup>2</sup>

( $p = 2,40$  kgf/cm<sup>2</sup>)

## AFT

IA Super:  $p = 0,45 + 0,013k$  max. 0,62 N/mm<sup>2</sup>

( $p = 4,60 + 0,130k$  max. 6,3 kgf/cm<sup>2</sup>)

IA:  $p = 0,34 + 0,009k$  max. 0,45 N/mm<sup>2</sup>

( $p = 3,50 + 0,090k$  max. 4,6 kgf/cm<sup>2</sup>)

IB:  $p = 0,23 + 0,005k$  max. 0,28 N/mm<sup>2</sup>

( $p = 2,40 + 0,050k$  max. 2,9 kgf/cm<sup>2</sup>)

IC:  $p = 0,118$  N/mm<sup>2</sup>

( $p = 1,20$  kgf/cm<sup>2</sup>)

where  $k = \frac{\sqrt{VH}}{858}$

$$\left( k = \frac{\sqrt{VH}}{1000} \right)$$

$V$  and  $H$  are as defined in 2460.

Where a calculated  $p$  value exceeds the given maximum value, the latter may be used in the formulae.

The  $k$  and  $p$  values used are to be stated on shell expansion and framing plans.

#### Transverse Framing

2462 The strength of transverse main and intermediate frames is to be determined by the formula:—

$$\frac{I}{y} = \frac{p s (l-400)}{8 f_y} \text{ cm}^3$$

where  $\frac{I}{y}$  = section modulus of the frame, in  $\text{cm}^3$ ,  
(including a width of attached plating equal to  $s$ ),

$p$  = pressure in the relevant region, as determined by 2461, in  $\text{N/mm}^2$  ( $\text{kgf/cm}^2$ ),

$s$  = distance, in mm, to the adjacent intermediate frame, or main frame if intermediate frames are not fitted,

$l$  = span, in mm, measured along the frame,

$f_y$  = yield stress of the steel, in  $\text{N/mm}^2$  ( $\text{kgf/cm}^2$ ).  
(For ordinary steel the value  $235 \text{ N/mm}^2$  ( $2400 \text{ kgf/cm}^2$ ) is to be used in all formulae concerning framing and plating.)

The Rule frame spacing may be modified to enable minimum increase in hull weight to be achieved.

Where end connections of intermediate frames differ from those of the main frames, giving different spans, the

mean span is to be used when determining main and intermediate frames. See Figs. D 24.1, D 24.2 and D 24.3, also 2482.

2463 The minimum vertical extension of transverse ice framing is to be as given in Table D 24.1.

#### Upper End of Framing

2464 Where not terminating at or above a 'tween deck, as indicated in 2465 and 2466, the upper end of intermediate frames is either to be extended to the deck above or to be attached to an ice stringer as in 2482. See Fig. D 24.1.

2465 Where the ice framing terminates 1000 mm or less above a 'tween deck, the above-deck part of the frames may have the scantlings of Rule 'tween deck frames. The upper end of intermediate frames is to be connected to the adjacent main frames by a horizontal member having the same scantlings as the main frames. Where the ice framing terminates less than 250 mm above a 'tween deck, the top part of intermediate frames may be omitted. See Fig. D 24.2.

2466 Where the ice framing terminates more than 1000 mm above a 'tween deck, the ends of main and intermediate 'tween deck frames are either to be attached to an ice stringer or to be extended to the deck above and may in that case be determined by the formula:—

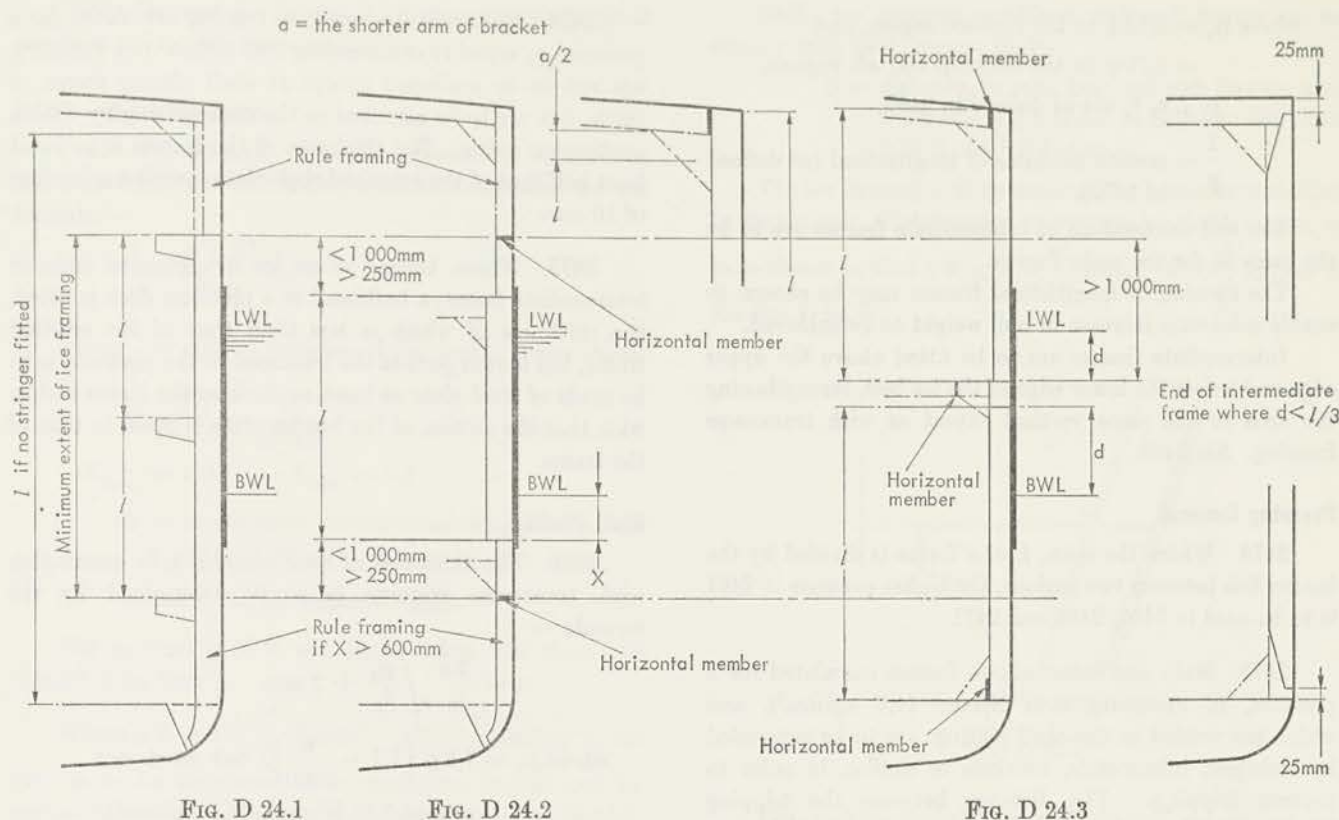
$$\frac{I}{y} = \frac{p s d (l-400) (l-d)}{2 f_y l^2} \text{ cm}^3$$

where  $d$ , in mm, is as indicated in Fig. D 24.3.

TABLE D 24.1

CLASS	EXTENT	POSITION	
		Above LWL	Below BWL
IA Super	From stem to 0,3L	1200 mm	to double bottom or below top of floors
	Aft 0,3L and Midship	1200 mm	1600 mm
	Aft	1200 mm	1200 mm
IA, IB and IC	From stem to 0,3L	1000 mm	1600 mm
	Aft 0,3L and Midship	1000 mm	1300 mm
	Aft	1000 mm	1000 mm





For Ice Class IA Super,  $(d+250)$  mm is to be used instead of  $d$  in the formula.

If  $d$ , or  $(d+250)$  as applicable, exceeds half the span  $l$ , the formula given in 2462 is to be used.

Where  $d$  is equal to or less than one-third of  $l$ , the end of intermediate frames may terminate not more than 25 mm below the deck, and need not be connected by a horizontal member.

NOTE. If the section modulus derived as above is less than that required by D 7, the latter is to be used.

#### Lower End of Framing

**2467** The lower end of intermediate frames is, except as indicated in 2468, either to be extended to approximately 25 mm above the margin plate or a corresponding distance below top of floors, or to be attached to a tank top, deck, or ice stringer. The ends are to be connected to adjacent brackets, floors or main frames by a horizontal member having the same scantlings as the main frames. See Fig. D 24.3.

**2468** Where the ice framing terminates less than 1000 mm below a deep-tank top, or a deck or an ice stringer,

the intermediate frame ends may be attached to adjacent main frames by a horizontal member as above. Where the distance is less than 250 mm, intermediate frames may terminate at a deep-tank top or deck. See Fig. D 24.2.

Alternatively, the section modulus may be determined as required by 2466, where this is appropriate.

**2469** In general, ice strengthened main frames are to extend to the bottom construction, but main frames below a deck, deep-tank top or ice stringer situated at least 600 mm below the BWL need only be of Rule scantlings.

**2470** In twin screw ships three intermediate frames forward of and three aft of the propeller blade tips are to extend to the double bottom.

The different parts of a frame are to be efficiently welded together. Frames are to be effectively attached to decks and stringers.

#### Longitudinal Framing

**2471** The strength of longitudinal frames is to be determined by the formula:—

$$\frac{I}{y} = \frac{p_2 l^2 s}{13\,000 f_y} \text{ cm}^3$$

where  $p_2 = 0,64 p$  in the forward region, and  
 $= 0,70 p$  in the midship and aft regions,

$p, l, s, f_y$  are as defined in 2462,

$\frac{I}{y}$  = section modulus of longitudinal (as defined in 2462).

The end connections of intermediate frames are to be the same as for the main frames.

The spacing of longitudinal frames may be chosen to enable minimum increase in hull weight to be achieved.

Intermediate frames are to be fitted above the upper edge and below the lower edge of the ice belt, strengthening the area to the same vertical extent as with transverse framing. See 2463.

#### Framing General

2472 Where the span,  $l$ , of a frame is divided by the border line between two regions, the higher pressure in 2461 is to be used in 2462, 2466 and 2471.

2473 Main and intermediate frames calculated for a pressure,  $p$ , exceeding  $0,45 \text{ N/mm}^2$  ( $4,6 \text{ kgf/cm}^2$ ), and which are welded to the shell plating, are to be supported by stringers, intercostals, brackets or similar, in order to prevent tripping. The distance between the tripping arrangements is not to exceed 1300 mm. See Fig. D 24.4.

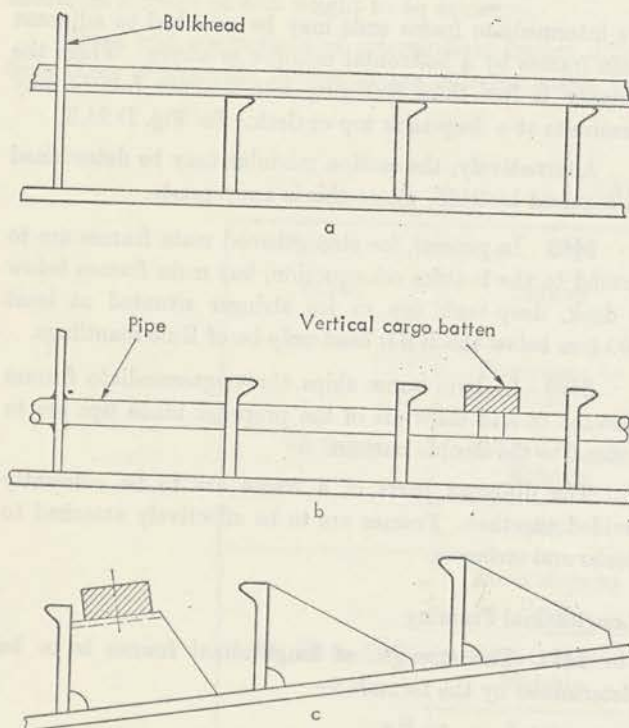


FIG. D 24.4

D 2472 - D 2479

2474 Main and intermediate frames, calculated for a pressure,  $p$ , equal to or exceeding  $0,45 \text{ N/mm}^2$  ( $4,6 \text{ kgf/cm}^2$ ), are not to be scalloped except at shell plating seams or butts, but are to be attached to the shell plating by double continuous welds. The thickness of the frames is to be at least half that of the attached shell plating with a minimum of 10 mm.

2475 Where, instead of an ice strengthened main or intermediate frame, a bulkhead or a platform deck is fitted, the thickness of which is less than that of the omitted frame, the border part of the bulkhead or the platform is to be made of steel plate at least as thick as the frame and so wide that the section of the border plate is equal to that of the frame.

#### Shell Plating

2476 The thickness of shell plating,  $t$ , in association with transverse framing is to be determined by the formula:—

$$t = \frac{2s}{3} \sqrt{\frac{p_3}{f_y}} + 2 \text{ mm}$$

where  $p_3 = 1,2 p \left(1,1 - \frac{s}{3000}\right)$ , but need not exceed  $1,62 \text{ N/mm}^2$  ( $16,5 \text{ kgf/cm}^2$ ),

$p, s$  and  $f_y$  are as defined in 2462.

The plating thickness is not to be less than that required by D 5 or D 43 as appropriate, but the frame spacing may be increased and the framing recalculated.

2477 The thickness of shell plating,  $t$ , in association with longitudinal framing is to be determined by the formula:—

$$t = \frac{2s}{3} \sqrt{\frac{p_4}{f_y}} + 2 \text{ mm}$$

where  $p_4 = 1,4 p$  in the forward region, and

$= 1,2 p$  in the midship and aft regions, but need not exceed  $1,62 \text{ N/mm}^2$  ( $16,5 \text{ kgf/cm}^2$ ),

$p, s$  and  $f_y$  are as defined in 2462.

2478 The vertical extension of the ice belt is to be, for Ice Class IA Super, from 750 mm above LWL to 600 mm below BWL, for Ice Class IA from 600 mm above LWL to 500 mm below BWL, and for Ice Classes IB and IC from 500 mm above LWL to 500 mm below BWL.

2479 The bottom plating and floors in the forward region are to be adequately strengthened, where the distance from the lower edge of the ice belt to the keel plate is less than 1500 mm or where the draught is less than 1500 mm.



2480 Changes in plating thicknesses in longitudinal direction are to take place gradually.

### Decks and Ice Stringers

2481 The strength of decks adjacent to hatchways and supporting the ice framing is to be determined by the formula:—

$$\frac{I}{y} = \frac{p K S^2}{22 f_y} \text{ cm}^3$$

where  $\frac{I}{y}$  = section modulus of the deck or ice stringer,

$$K = 1,1 - \frac{S}{10\,000},$$

$$K_{\max.} = 1,0 \quad K_{\min.} = 0,7$$

$S$  = transversely unsupported length of hatchway, in mm,

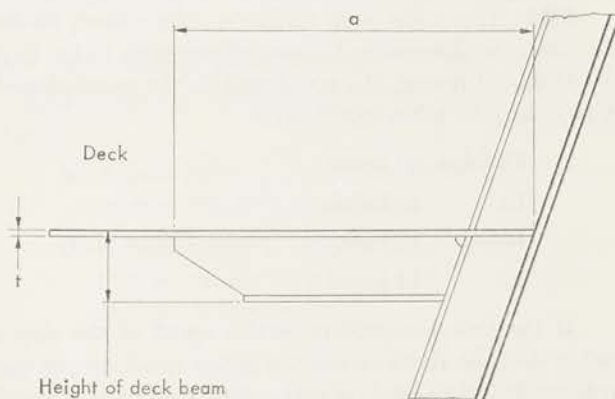
$p$  and  $f_y$  are as defined in 2462.

The product  $p K$  is not to be taken less than 0,69 N/mm<sup>2</sup> (7 kg f/cm<sup>2</sup>).

Where  $p K \geq 470 \frac{t^3}{r^2}$  N/mm<sup>2</sup> (4800  $\frac{t^3}{r^2}$  kgf/cm<sup>2</sup>), the deck is to be supported at intermediate frames and by partial beams or brackets in accordance with Fig. D 24.5;  $r$  being the deck beam spacing, in mm.

The required shear area,  $A$ , of the deck in way of hatch corners is not to be less than:—

$$A = \frac{4,2 p K S}{f_y} \text{ cm}^2$$



$t$  = thickness of deck plating, in mm  
 $a \geq 150 + 612 p K$  mm  
 $(a \geq 150 + 60 p K)$  mm

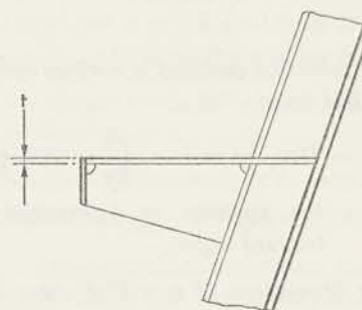
FIG. D 24.5

2482 Ice stringers combined with web frames are to comply with 2481, except that:—

$S$  = distance, in mm, between web frames, and the product  $p K$  is not to be taken less than 0,48 N/mm<sup>2</sup> (5 kgf/cm<sup>2</sup>).

The ice framing is to be attached by brackets or similar to the stringer. The distance,  $r$ , between brackets, in mm, is to be chosen so that  $p K \leq 470 \frac{t^3}{r^2}$  N/mm<sup>2</sup> (4800  $\frac{t^3}{r^2}$  kgf/cm<sup>2</sup>).

See Fig. D 24.6.



$t$  = thickness of stringer in mm

FIG. D 24.6

The section modulus of web frames supporting ice stringers or longitudinal frames is determined by the formula:—

$$\frac{I}{y} = \frac{p K S Z}{12,5 f_y} \text{ cm}^3$$

where  $K$  is as defined in 2481,

$p$  and  $f_y$  are as defined in 2462,

$Z$  = span of web frame, in mm,

$p K$  is not to be taken less than 0,48 N/mm<sup>2</sup> (5 kgf/cm<sup>2</sup>).

The required shear area of the web frame supporting one stringer is determined by 2481. For a web frame supporting several ice stringers or longitudinal frames, the shear area, determined by 2481 should be increased by 50 per cent.

Where ice stringers are fitted, the span,  $L$ , in 2462 for determining main and intermediate frames may be taken as the distance between ice stringers or between stringer and deck.

### Stem

2483 The stem is to be made of rolled, cast or forged steel, or of shaped steel plates. A sharp edged stem (as in Fig. D 24.7) improves the ability to cut into ice, in particular when the length of the ship is less than 150 m.

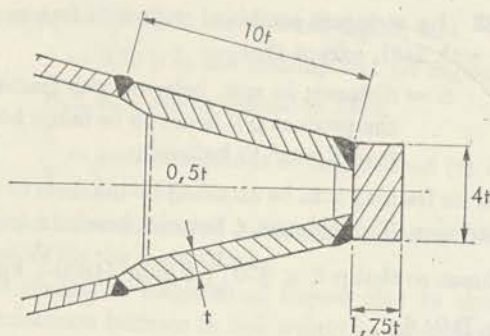


FIG. D 24.7

2484 The section modulus in the fore and aft direction is not to be less than:—

$$\frac{I}{y} = 715 \sqrt{p^3} \text{ cm}^3 \quad \left( \frac{I}{y} = 22 \sqrt{p^3} \text{ cm}^3 \right)$$

where  $p$  = the pressure as determined by 2461—forward region.

(a) The dimensions of a welded stem as shown in Fig. D 24.7 are determined by the formula:—

$$t = 24,3 \sqrt{p} \text{ mm} \quad (t = 7,6 \sqrt{p} \text{ mm})$$

where  $t$  = thickness of the side plates, in mm, and

$p$  = the pressure as determined by 2461—forward region.

The reinforced stem is to be extended from the keelplate up to 750 mm above the load waterline and is to be internally strengthened by floors, brackets or webs having a thickness of at least  $t/2$  mm and spaced not more than 600 mm apart.

(b) The plate thickness,  $t$ , of a shaped plate stem or a bulbous bow is determined by the formula:—

$$t = \frac{4s}{5} \sqrt{\frac{p_4}{f_y}} + 2 \text{ mm}$$

where  $p_4 = 1,4 p$  for the forward region,

$s$  = the distance, in mm, between horizontal webs or diaphragm plates, having a thickness of at least  $t/2$  mm,

$f_y$  is as defined in 2462.

Where in the ice belt region the curvature of the stem or bulb front plating is large, one or several vertical stiffener(s) is(are) to be fitted in order to meet the section modulus requirement.

(c) The dimensions of the stem may be tapered to the requirements of D 12 at the upper deck.

(d) The connections of the shell plating to the stem are to be flush.

2485 A mooring pipe with an opening not less than 250 by 300 mm and a rounding radius not less than 100 mm of inner surfaces at least 150 mm wide is to be fitted in the centreline of the bow bulwark, for towing purposes. A bitt or other convenient means of securing the line is to be dimensioned to withstand the Rule breaking strength of the ship's towline.

2486 Strengthening of the bow plating and framing in an area 2 to 3 m from the stem abaft and 4 to 5 m in height above the LWL is recommended, to take account of the stresses occurring when the ship is in short tow in the icebreaker's stern fork.

Ships, the bulbous bows of which extend more than 2 m forward of the forward perpendicular, cannot be taken in short tow by existing Finnish-Swedish icebreakers.

#### Stern Frames

2487 Where the screwshaft diameter exceeds the Rule diameter, the propeller post is to be correspondingly strengthened. See D 1215.

#### Bossings and Shaft Struts

2488 Shaftings and sterntubes of ships with two or more propellers are to be enclosed within plated bossings. If detached supporting struts are absolutely unavoidable, their design, strengthening and attachment to the hull are to be duly considered.

#### Rudder and Steering Arrangements

2489 The rudder post, solepiece, rudder head, pintles, etc., are to be dimensioned in accordance with D 12, D 22 and D 23. However, the speed used in the calculations is in no case to be taken less than:—

IA	Super 20 knots
IA	18 knots
IB	16 knots
IC	14 knots

If the actual maximum service speed of the ship is higher than the above values, the higher speed is to be used in the calculations, and no extra strengthening is required.

2490 For double plate rudders, the minimum thickness of plates and horizontal and vertical webs in the ice belt region is to be determined as for shell plating in the aft region in accordance with 2477.



**2491** The rudder head and the upper edge of the rudder are to be protected against ice pressure by an ice knife or equivalent means, for the Ice Classes IA Super and IA.

**2492** Efficient rudder stops, a slip coupling or equivalent arrangements are to be fitted in order to protect the steering gear against excessive external loading.

## Section 25

### DECK LOADING

#### Permissible Cargo Loading on Decks and Hatch Covers having Minimum Rule Scantlings

##### Weather Decks

**2501** Loading equivalent to a head of 1,2 m with a stowage rate of 1,39 m<sup>3</sup>/tonne, i.e. 8,53 kN/m<sup>2</sup> (0,87 tonne-f/m<sup>2</sup>).

##### Cargo Decks

**2502** Loading equivalent to a head equal to the 'tween deck height (*h* metres) with a stowage rate of 1,39 m<sup>3</sup>/tonne, i.e. 7,06 *h* kN/m<sup>2</sup> (0,72 *h* tonne-f/m<sup>2</sup>). *See also* 2504.

##### Weather Deck Hatch Covers

**2503** For hatch covers fitted on weather decks in positions 1 and 2 (*see* D 2605), the maximum cargo load is that equivalent to a head of 1,5 m and 1,2 m respectively, with a stowage rate of 1,39 m<sup>3</sup>/tonne, i.e. 10,59 kN/m<sup>2</sup> (1,08 tonne-f/m<sup>2</sup>) in position 1 and 8,53 kN/m<sup>2</sup> (0,87 tonne-f/m<sup>2</sup>) in position 2, unless the supporting deck girders and pillars are increased in size, in which case, *see* 2509 and 2510.

#### Lower Decks forming Crown of Deep or Tunnel Tanks

**2504** Loading equivalent to the greater of the following:—

- (a) A head equal to the 'tween deck height with a stowage rate of 1,39 m<sup>3</sup>/tonne,
- (b) A head equal to one-half the height of the air pipe above the tank crown with a stowage rate of 0,975 m<sup>3</sup>/tonne.

##### Inner Bottom

**2505** For ships having the class 100A1 the loading on the tank top may be that equivalent to a head of 1,4 *d* with a stowage rate of 1,39 m<sup>3</sup>/tonne. *d* is the load draught, in metres.

For ships of Type 1 (*see* D 318) the inner bottom may be suitable for increased loads—*see* D 606.

#### Specified Cargo Loading on Decks and Hatch Covers in excess of that given in 2501 to 2504

**2506** If the actual loading is in excess of the nominal Rule loading, then the appropriate *h* values, with the exceptions given in 2507, 2508, 2509 and 2510, are to be increased in direct proportion.

**2507** For weather deck hatch side coamings, hatch end beams, girders and pillars, the head *h* to be used is 0,14 *p* m (1,39 *p* m), plus an allowance for weather as follows:—

- (a) where the basic *h* as obtained from D 6 or D 8 is 1,2 m or less, allowance for weather = 0.
- (b) where *h* obtained from D 6 or D 8 is 1,5 m, allowance for weather = 0.

(Intermediate values are to be in proportion.)

*p* = actual deck loading in kN/m<sup>2</sup> (tonne-f/m<sup>2</sup>).

**2508** For deck longitudinals and beams, the scantlings are to be obtained from D 604 and D 809, using the head obtained from 2506 for cargo decks and 2507 for weather decks. The modulus of weather deck longitudinals or beams is not to be less than that obtained from D 602 and D 806.

**2509** Hatch covers in position 1 need not be increased where the head obtained from 2506 (i.e. without any addition for weather) is 2,44 m or less; when it exceeds 2,44 m the scantlings are to be increased in direct proportion.

**2510** Hatch covers in position 2 need not be increased where the head obtained from 2506 (i.e. without any addition for weather) is 1,8 m or less; when it exceeds 1,8 m the scantlings are to be increased in direct proportion.

**2511** Where heavy loads are to be carried, the side framing in way may require to be strengthened.

#### Concentrated Loads

**2512** Where provision is required for concentrated loads, then scantlings and arrangements will be considered.

*See* D 421 and D 811 for wheeled vehicles.

#### Hanging Cargoes

**2513** For hanging cargoes, *see* D 603, D 605, D 807 and D 810.

#### Fruit or similar Light Cargoes

**2514** Where the deck is designed for the carriage of fruit or similar light cargoes only, the head used for the calculations can be reduced in a similar manner to that given in 2506 but is not to be taken as less than 1,2 m.

**Timber Deck Cargoes**

2515 On ships with timber deck cargoes, the value of  $h$  for decks where timber is to be carried is not to be less than 1,5 m.

Where the height to which timber is to be stowed exceeds 2,3 m, the value of  $h$  is to be increased in the ratio of actual height to 2,3 m, i.e. the timber stowage rate may be assumed to be 2,1 m<sup>3</sup>/tonne.

No additional allowance for weather need be made.

**Direct Calculations**

2516 As an alternative to the above, permissible deck loads may be determined by direct calculation using a two- or three-dimensional grillage idealization.

The calculated stresses, due to deck loading only, are not to exceed:—

$\frac{123,6}{k} \text{ N/mm}^2 \left( \frac{12,6}{k} \text{ kgf/mm}^2 \right)$  for longitudinal items included in the hull modulus calculation, other than hatch side girders and deck longitudinals.

$\frac{101}{k} \text{ N/mm}^2 \left( \frac{10,3}{k} \text{ kgf/mm}^2 \right)$  for hatch side girders included in the hull modulus calculation and also for deck longitudinals.

$\frac{123,6}{k} \text{ N/mm}^2 \left( \frac{12,6}{k} \text{ kgf/mm}^2 \right)$  for all other strength deck members.

$\frac{130,4}{k} \text{ N/mm}^2 \left( \frac{13,3}{k} \text{ kgf/mm}^2 \right)$  for lower deck members.

In all the above members, the shear stress is not to exceed  $\frac{83,4}{k} \text{ N/mm}^2 \left( \frac{8,5}{k} \text{ kgf/mm}^2 \right)$   
 $k$  is the higher tensile steel factor, see D 116.

The assumed loadings in these calculations are to include suitable allowances for weather, generally 2,16 kN/m<sup>2</sup> (0,22 tonne-f/m<sup>2</sup>), where the weather deck is the free-board deck.

For timber deck cargoes, wet softwood may be assumed to have a stowage rate of 1,45 m<sup>3</sup>/tonne as solid wood, or of 2,1 m<sup>3</sup>/tonne based on the whole volume from bulwark to bulwark and deck to top of timber, including normal battens, etc.

Where the calculated stresses are lower than the allowed stresses, the minimum Rule scantlings for pillars, girders, beams, etc., must still be maintained.

For recommendations for deck plating for wheeled vehicles, see D 421.

**Section 26****HATCHWAYS AND DECK OPENINGS**

*Note. Where relevant, the contents of this Section conform with the requirements of the 1966 Load Line Convention.*

**Definitions**

2601  $L$  = length of ship, in metres.

$h$  = head, in metres, and is to be taken as follows:—

For position 1

$$h = 1,07 + \frac{L}{72,5} \text{ m}$$

but need not exceed 2,45 m

For position 2

$$h = 0,8 + \frac{L}{100} \text{ m}$$

but need not exceed 1,8 m

For definitions of positions 1 and 2—see 2605.

The above heads apply in conjunction with a stowage rate of 1,39 m<sup>3</sup>/tonne.

In 'tween decks,

$h$  = 'tween deck height, in metres, measured vertically on the centreline of the ship from deck to deck.

Provided the loading does not exceed that corresponding to a stowage rate of 1,39 m<sup>3</sup>/tonne, hatch coamings situated above and which have a height not exceeding 1,0 m may be ignored.

Where the specified loading exceeds that corresponding to a stowage rate of 1,39 m<sup>3</sup>/tonne, or where the hatch coamings situated above exceed 1,0 m in height, then an equivalent  $h$  is to be used.  
 See also D 2506.

The following definitions apply to webs or stiffeners with attached plating, or portable beams:—

$l_0$  = unsupported span, in metres, measured as shown in Fig. D 26.1,

$l_1$  = proportion of the span, in metres, measured as shown in Fig. D 26.1; the depth and face area over the remainder of the span is assumed to be constant,

$s$  = spacing, in mm,



$d$  = overall depth at the supports, measured as shown in Fig. D 26.1, but is not to be less than 150 mm—see also definition of  $I_1$ ,

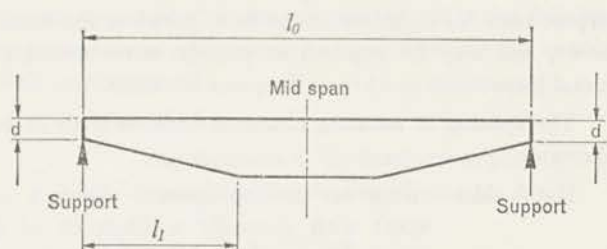


FIG. D 26.1 DIAGRAMMATIC PROFILE OF WEB OR STIFFENER OR PORTABLE BEAM

$$\alpha = \frac{l_1}{l_0}$$

$\left(\frac{I}{y}\right)_0$  = section modulus, in  $\text{cm}^3$ , at mid-span,

$\left(\frac{I}{y}\right)_1$  = section modulus, in  $\text{cm}^3$ , at supports,

$$\gamma = \frac{\left(\frac{I}{y}\right)_1}{\left(\frac{I}{y}\right)_0}$$

$$K = 1 + \frac{3,2\alpha - \gamma - 0,8}{7\gamma + 0,4} \begin{cases} \text{To be specially} \\ \text{considered when} \\ \text{discontinuities in} \\ \text{area of face mat-} \\ \text{erial occur,} \end{cases}$$

but not less than 1,0

$I_0$  = moment of inertia, in  $\text{cm}^4$ , at mid-span,

$I_1$  = moment of inertia, in  $\text{cm}^4$ , at supports, and is not to be less than  $0,05 I_0$

$$\beta = \frac{I_1}{I_0}$$

$$C = 1 + \frac{8\alpha^3(1-\beta)}{0,2 + 3\sqrt{\beta}} \begin{cases} \text{To be specially} \\ \text{considered when} \\ \text{discontinuities in} \\ \text{area of face mat-} \\ \text{erial occur,} \end{cases}$$

$\sigma_b$  = the comprehensive bending stress, in  $\text{N/mm}^2$  ( $\text{kgf/mm}^2$ ), in the steel cover plating, calculated by taking the cover as a loaded beam simply supported at its ends,

$\sigma_c$  = critical buckling stress of panel, in  $\text{N/mm}^2$  ( $\text{kgf/mm}^2$ ),

$\sigma_{ac}$  = corrected critical buckling stress, in  $\text{N/mm}^2$  ( $\text{kgf/mm}^2$ ),

$\sigma_y$  = yield stress of cover plating material, in  $\text{N/mm}^2$  ( $\text{kgf/mm}^2$ ),

$t$  = thickness of the cover plating, in mm,

$b$  = length of panel, in mm, in transverse direction. See Fig. D 26.2.

#### Application

**2602** The scantlings given in this Section apply basically to rectangular covers with the stiffening members arranged primarily in one direction, and carrying a uniformly distributed load. Where covers have members arranged in a grillage formation, and/or point loads are applied, the scantlings of the covers will be specially considered.

#### Other Materials

**2603** The scantlings given in this Section are applicable to mild steel. Where other materials, such as aluminium are to be used, equivalent scantlings are to be provided.

#### WEATHER DECK HATCHWAYS

**2604** For the purposes of this Section, four basic types of ship are defined:—

- B—100 cargo ships with tanker freeboard,
- B—60 cargo ships with intermediate freeboard,
- B cargo ships with "Type B" freeboard,
- B+ cargo ships with increased freeboard.

#### Position of Hatchways

**2605** Position 1, hatchways on exposed freeboard and raised quarter decks, and exposed superstructure decks within the forward  $0,25L$ .

Position 2, hatchways on exposed superstructure decks abaft the forward  $0,25L$ .

#### Steel Covers Fitted with Direct Securing Arrangements for "B—100", "B—60" or "B" Type Ships

**2606** These are plated covers stiffened by webs or stiffeners, weathertightness being obtained by gaskets and clamping devices.

The section modulus and moment of inertia of the webs or stiffeners are to satisfy the following formulæ respectively:—

$$(a) \quad \frac{h s l_0^2 K}{107,5 \left(\frac{I}{y}\right)_0} \leq 1$$

$$(b) \quad \frac{h s l_o^3 C}{63,7 I_o} \leq 1$$

The thickness of the cover is not to be less than:—

$$t = \frac{s}{100} \text{ mm or } 6 \text{ mm, whichever is the greater.}$$

Where  $h$  exceeds 3,5 m the above thicknesses are to be increased by the factor

$$\sqrt[3]{\frac{h}{3,5}}$$

**2607** Where cover plate stiffening is fitted normal to the axis of primary bending as indicated in Fig. D 26.2 the plating is also to satisfy the following requirements:—

$$\frac{\sigma_c}{\sigma_b} \left( \text{or } \frac{\sigma_{ac}}{\sigma_b} \right) \text{ equal to or greater than } 1,3$$

$$\text{where } \sigma_c = 18,6 R \left( \frac{t}{b} \right)^2 \times 10^4 \text{ N/mm}^2$$

$$\left( \sigma_c = 1,9 R \left( \frac{t}{b} \right)^2 \times 10^4 \text{ kgf/mm}^2 \right)$$

$$R = \left( \frac{s}{b} + \frac{b}{s} \right)^2$$

If  $\sigma_c$  is greater than  $\sigma_y/2$ , then a corrected value  $\sigma_{ac}$  is to be obtained from:—

$$\sigma_{ac} = \sigma_y \left( 1 - \frac{\sigma_y}{4 \sigma_c} \right) \text{ N/mm}^2 \text{ (kgf/mm}^2 \text{)}$$

It is recommended that  $\frac{b}{s}$  is not greater than 5.

**2608** Covers having primary stiffening in two directions will be specially considered.

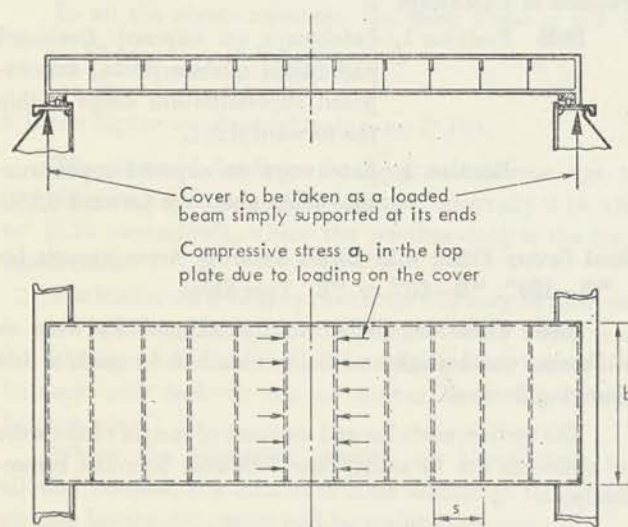


FIG. D 26.2 COVER WITH STIFFENING FITTED NORMAL TO THE AXIS OF PRIMARY BENDING

**2609** Securing cleats and cross joint wedges, together with suitable jointing material, are to be fitted to secure the weathertightness of the covers to the satisfaction of the Surveyors. The arrangements are to ensure that the tightness can be maintained in any sea conditions, and for this purpose tests for tightness are to be required at the initial survey, and may be required at periodic surveys and at annual inspections or at more frequent intervals.

The spacing of securing cleats on hatches is to be as follows:—

**Hatch sides**—cleats are to be spaced about 2 m apart with generally a minimum of 2 cleats per panel. Where hydraulic or mechanical means of securing are employed one securing device per panel will be considered assuming arrangements are provided for inter-locking the panels.

**Hatch ends**—cleats are to be spaced about 2 m apart with one arranged adjacent to each corner.

Cross joint wedges to be spaced about 1,5 m apart. Alternatively, where positive securing devices are arranged on the lower side of the joint to ensure continuing compression of the joint, these can be accepted about 3,0 m apart.

Steel hatch covers with special sealing arrangements or insulated covers will be specially considered.

**2610** Where it is proposed to omit coamings on weather decks, the strength and closing arrangements of the hatch covers will be specially considered.

**2611** Where hatch covers are fitted to holds used as tanks the strength, stiffness, sealing and securing arrangements will be specially considered.

#### Steel Pontoon Covers—For “B” Type Ships Only

**2612** These are plated covers having interior webs and stiffeners, extending for the full width of the hatchway and about a quarter of the length, and not fitted with direct securing arrangements.

The section modulus and moment of inertia of the webs or stiffeners are to satisfy the following formulæ respectively:—

$$(a) \quad \frac{h s l_o^2 K}{91,3 \left( \frac{I}{y} \right)_o} \leq 1$$

$$(b) \quad \frac{h s l_o^3 C}{50 I_o} \leq 1$$

The plating thickness is to be as required by 2606 and 2607.



**2613** The requirements of 2624 to 2628 are to be complied with.

#### Hatch Covers for Holds used for Liquid Cargoes

**2614** Hatch covers for holds in OBO, ORE or OIL and similar types of ship are to comply with the following requirements in addition to the requirements for weather deck hatchways.

(a) Plate thickness.

The thickness of the hatch cover plating is not to be less than the greatest of:—

$$(i) \quad t = \frac{s}{100} + 0,5 \text{ mm}$$

$$(ii) \quad t = 0,0025s \sqrt{\chi} + 2,5 \text{ mm}$$

where  $\chi$  = distance from ship centreline to the outboard edge of the plate under consideration, in metres,

$$(iii) \quad t = 8,5 \text{ mm}$$

(b) Strength of stiffeners.

Primary transverse and longitudinal stiffeners are to have a section modulus and moment of inertia not less than:—

$$(i) \quad \left( \frac{I}{y} \right)_o = \frac{h s l_o^2 K}{107,5} \text{ cm}^3$$

$$(ii) \quad I_o = \frac{h s l_o^3 C}{46,3} \text{ cm}^4$$

The value of  $h$  in the above formulæ is to be the greater of:—

$h$  for weather deck hatch cover, *see* 2601, or 0,45 times the distance of the mid-point of the stiffener from the ship's centreline, in metres.

(c) Secondary panel stiffeners.

Secondary panel stiffeners are to have a section modulus and moment of inertia derived as for longitudinal primary stiffening, using the appropriate span and spacing. Where the ends of stiffeners are effectively fixed, the section modulus may be 67 per cent and the inertia 20 per cent of the values derived from the above formulæ.

(d) Cross stiffened covers.

Where the primary stiffening is arranged in both directions as a grillage, the scantlings are to be determined by direct calculation.

For this purpose, the loading is to be taken as that corresponding to the ship heeled to 22,5 degrees with the surface of the liquid intersecting

the hatch cover top line at the centreline of the ship. The maximum permissible stress for this loading is to be 118 N/mm<sup>2</sup> (12 kgf/mm<sup>2</sup>).

(e) Minimum thickness.

The thickness of structural members is not to be less than 8,5 mm.

(f) Securing arrangements.

The spacing and size of cleats or other securing arrangements will be considered in relation to the calculated edge forces and proposed packing arrangements.

Paragraphs 2615 to 2628 refer to hatch covers used in conjunction with portable beams, and not using direct securing arrangements, and may be fitted on "B+" ships only.

#### Wood Covers

**2615** Wood covers at positions 1 and 2 are to have a thickness not less than 60 mm in association with an unsupported span of 1,5 m, and 82 mm with 2 m; the thicknesses for intermediate spans are to be in proportion.

**2616** The ends of all wood hatch covers are to be protected by encircling galvanized steel bands about 65 mm wide and 3 mm thick, efficiently secured.

#### Portable Steel Covers

**2617** The section modulus and moment of inertia of stiffeners is to be in accordance with 2606. The thickness of plating is not to be less than:—

$$t = \frac{s}{100} \text{ mm or } 3,5 \text{ mm}$$

whichever is the greater.

#### Hatch Rests

**2618** Hatch rests are to provide at least 65 mm bearing surface and are to be bevelled if required to suit the slope of the hatches.

#### Portable Hatch Beams

**2619** The section modulus and moment of inertia of portable web plate beams stiffened at their upper and lower edges by continuous flat bars are to satisfy the following formulæ respectively:—

$$(a) \quad \frac{h s l_o^2 K}{91,3 \left( \frac{I}{y} \right)_o} \leq 1$$

$$(b) \quad \frac{h s l_o^3 C}{50 I_o} \leq 1$$



**2620** The ends of web plates are to be doubled or inserts fitted at least 180 mm wide.

**2621** At beams which carry the ends of wood or steel hatch covers, a vertical 50 mm flat is to be arranged on the upper face plate, and the bearing surface for hatch covers is not to be less than 65 mm.

**2622** Portable beams are to be supported at their ends by carriers, sockets or other suitable arrangements, having a minimum bearing surface of 75 mm.

**2623** Sliding hatch beams are to be provided with an efficient device for locking them in their correct fore and aft positions when hatchway is closed.

#### Tarpaulins and Securing Arrangements

**2624** At least two layers of tarpaulin in good condition are to be provided for each hatchway in positions 1 or 2.

**2625** Tarpaulins are to be free from jute, thoroughly waterproofed and of ample strength. The minimum weight of the material before treatment is to be 0,65 kg/m<sup>2</sup> if the material is to be tarred, 0,60 kg/m<sup>2</sup> if to be chemically dressed, or 0,55 kg/m<sup>2</sup> if to be dressed with black oil.

A certificate to the above effect is to be supplied by the makers of the tarpaulins.

Special consideration will be given when covers of synthetic material are proposed in lieu of tarpaulins.

**2626** Cleats are to be of an approved pattern at least 65 mm wide, with edges so rounded as to minimize the cutting of the wedges, and are to be spaced not more than 600 mm from centre to centre; the cleats along each side or end are to be arranged not more than 150 mm from the hatch corners.

The thickness should not be less than 9,5 mm for angle cleats, and 11 mm for smithed cleats which should be stiffened by pressing out the centre to form a web extending to the bottom of the palm. Drop forgings should be of equivalent strength. Cleats should be so set as to fit the taper of the wedges.

**2627** Battens and wedges are to be efficient and in good condition. Wedges are to be of tough wood, generally not less than 200 mm in length and 50 mm in width. They should have a taper of not more than 1 in 6 and should not be less than 13 mm at the point.

**2628** For all hatchways in positions 1 and 2, steel bars or other equivalent means are to be provided to secure, efficiently and independently, each section of the hatch covers after the tarpaulins are battened down.

Hatch covers of more than 1,5 m in length are to be secured by at least two such securing appliances. Where hatchway covers extend over intermediate supports, steel bars or their equivalent are to be fitted at each end of each section of covers. At all other hatchways in exposed positions on weather decks ring bolts or other fittings for lashings are to be provided.

#### Hatchway Coamings

**2629** The height of coamings above the upper surface of the deck, measured above sheathing if fitted, for hatchways closed by portable covers secured weathertight by tarpaulins and battening devices is not to be less than:—

Position 1, 600 mm

Position 2, 450 mm

The height of coamings of hatchways situated in positions 1 or 2 and closed by steel covers fitted with direct securing arrangements are to be as specified above, but may be reduced or the coamings omitted entirely if the safety of the ship is not impaired in any sea conditions.

In the case of flush hatch covers or those having coamings less than stated in this paragraph the scantlings and securing arrangements will be specially considered.

**2630** Hatchways on other decks and in positions not detailed in 2629 are to be suitably framed.

#### Construction of Weather Deck Coamings

**2631** The thickness of hatch coamings is not to be less than 11 mm.

**2632** Coamings 600 mm or more in height are to be stiffened on their upper edges by a horizontal bulb flat or equivalent not less than 180 mm in depth. Additional support is to be afforded by fitting brackets or stays from the bulb flat to the deck at intervals of not more than 3 m.

Coamings less than 600 mm in height are to be stiffened on their upper edges by a substantial moulding.

**2633** The scantlings and arrangements of coamings more than 900 mm in height and of coamings acting as girders will be specially considered.

**2634** Side coamings of all hatchways are to extend at least to the lower edge of the deck beams which are to be effectively attached to the coamings as required by Table D 32.1.

**2635** Extension brackets or rails arranged approximately in line with the hatch side coamings and intended for stowage of steel covers are not to be welded to a deck-house, masthouse, or to each other, unless they form part of the longitudinal strength members.



**2636** For details of arrangement of coamings at hatch corners, see D 424.

#### HATCH COVERS IN CARGO OR ACCOMMODATION SPACES

**2637** In cargo spaces, steel hatch covers (including pontoon covers) and portable hatch beams are to have scantlings and arrangements as required by 2606, but modified as follows:—

- (a) The section modulus may be 6 per cent less than given by 2606 (a)
- (b) The inertia requirements may be 20 per cent less than given by 2606 (b)
- (c) A check on panel stability including critical buckling as given in 2607.

**2638** In accommodation spaces, the 'tween deck height,  $h$ , is to be taken as 1,8 m.

**2639** Wood covers are to have a thickness not less than 60 mm in association with an unsupported span of 1,5 m, and 82 mm with 2 m; the thicknesses for intermediate spans are to be in proportion.

When the 'tween deck height,  $h$ , exceeds 2,6 m the thickness of the covers is to be increased at the rate of 16,5 per cent per metre excess in 'tween deck height.

For details of wood covers, see 2616.

#### Wheeled Vehicles

**2640** Where wheeled vehicles are to be used, the thickness of the hatch cover plating is to be in accordance with D 421 and D 423, and the modulus of the stiffeners is to be not less than:—

$$\frac{I}{y} = F_1 T l + \frac{F_2 h l^2 s}{600} \text{ cm}^3$$

but neither is to be less than required by 2637.  $F_1$  and  $F_2$  are coefficients obtained from Table D 26.1, and  $T$  = total weight of truck and its load in tonnes.

Where unusual arrangements of hatch cover stiffening are proposed, the scantlings of stiffeners may be approved on the basis of grillage type calculation.

#### Tank Hatch Covers in 'Tween Decks

**2641** The scantlings of steel tank hatch covers situated in 'tween decks are to be determined as for cargo deck hatch covers but the scantlings must in no case be less than would be required by D 19 for a deep tank bulkhead.

The maximum spacing of cleats and cross joint wedges is to be 600 mm, but cleats are to be arranged as close as practicable to the corners.

TABLE D 26.1

WHEEL SPACING * STIFFENER SPAN	$F_1$	$F_2$
0,1	11,96	2,32
0,2	10,69	1,89
0,3	9,58	1,55
0,4	8,46	1,28
0,5	7,46	1,07
0,6	6,51	0,91
0,7	5,55	0,73
0,8	4,23	0,36
0,9	2,38	0,11

\*Outer wheel to outer wheel on axles with multiple wheel arrangements.

#### GENERAL

##### Bunker, Access and Trimming Hatchways

**2642** The construction and the closing and securing arrangements of bunker, access and trimming hatchways are to comply with the requirements of 2601 to 2636 so far as applicable.

##### Manholes and Flush Scuttles

**2643** Manholes and flush scuttles fitted in positions 1 or 2 or within superstructures other than enclosed superstructures, are to be closed by substantial covers capable of being made watertight. Unless secured by closely spaced bolts, the covers are to be permanently attached.

##### Trunked Hatchways

**2644** Where hatchways are trunked through one or more 'tween decks, and hatchway beams and covers are dispensed with at the intermediate decks, the hatchway beams, coamings and covers immediately below the trunk are to be adequately strengthened; plans are to be submitted for approval.

##### Means of Escape

**2645** In and from all crew and passenger spaces and spaces in which crew are normally employed, other than machinery spaces, stairways and ladders are to be arranged so as to provide ready means of escape to the lifeboat embarkation deck. For means of escape from machinery spaces, see D 2113.



**Companionways and Doors**

**2646** The construction and arrangement of companionways and doors is to comply with D 1726 to D 1729.

**2647** The height, measured above deck sheathing if fitted, of doorway sills in position 1 is generally not to be less than 600 mm. Consideration will, however, be given to reduction of this height where this is permitted by the regulations of the National Authority of the country in which the ship is to be registered.

The height, measured above deck sheathing if fitted, of doorway sills in position 2, and in position 1 where the door is not protecting an access to below the freeboard deck, is generally not to be less than 380 mm.

**2648** Where, in ships with Type "A", "B-100" or "B-60" freeboards, there is direct access to the machinery space from the freeboard deck, the outer and inner weather-tight doors are generally to have sill heights not less than 600 mm and 230 mm respectively.

**2649** The height of door sills may require to be increased on ships with Type "A", "B-100" or "B-60" freeboards where this is shown to be necessary by the floatability calculations.

**2650** The sill heights of accesses closed by covers which are secured by closely spaced bolts or otherwise kept permanently closed at sea will be specially considered.

**Cross-reference**

**2651** For welding requirements, see Table D 32.1.

**Section 27****MASTS AND RIGGING**

**2701** The scantlings of steel masts and derrick posts intended to support derrick booms of 15 tonnes S.W.L. and under are to be determined from the greatest stresses expected to arise when the cargo gear is correctly used. The scantlings of masts and derrick posts supporting one or more derrick booms with a S.W.L. exceeding 15 tonnes and those of bipod or other special designs including stayed masts where the stays are attached to the outer end of crosstrees will be considered in accordance with the Society's *Code of Practice for the Construction and Survey of Ship's Cargo Handling Gear*.

Mild steel used for masts, derrick posts, etc., and their associated crosstrees and brackets is to be of D quality if the thickness exceeds 20,5 mm.

**2702** A stayed mast or derrick post is one that is supported by one or more stays. A "stay" includes shrouds, forestays, backstays, etc.

**Calculations—General**

**2703** The derrick or derricks are to be assumed to be initially at an angle of 30° to the horizontal or at the minimum angle specified (by the owner or builder) if this is less than 30°, the angles being measured when the ship is upright and without trim, but for calculations made with derricks swung outboard the effect of heel is to be taken into account if the heel of the ship is likely to exceed 5° with the derrick booms in this position and whilst working as swinging derricks carrying the full S.W.L.

**Stayed Masts and Posts**

**2704** The scantlings of stayed masts and stayed derrick posts are generally to be obtained from Table D 27.1 and the required size of their associated stays are to be obtained from Tables D 27.1, D 27.2 and D 27.3 by the method given in 2705 to 2711.

Where two sets of derricks with horizontal span tackle pull resultants which vary by more than 20 per cent of the higher value are fitted to the same mast, then, if the mast is a stayed mast, a full stress calculation must be submitted—see Note to Table D 27.1.

**2705** Calculations should normally be submitted for the following conditions:—

- (a) For masts with four derricks:—
  - (i) with two derricks plumbing one hatch;
  - (ii) with two derricks swung to their most outboard working position on one side of the ship.
- (b) For masts with one derrick fitted forward and one aft:—
  - (i) with one derrick at its greatest working outreach in a fore and aft direction;
  - (ii) with both derricks swung to their most outboard working position on one side of the ship.

In each case the above derricks are to be considered as swinging derricks carrying the full S.W.L.

If other arrangements seem likely to give stresses significantly larger than either of the above, then a calculation is to be made for this "worst" configuration in addition to the others.

**2706** The "Resultant of horizontal pulls of span tackles" is to be the resultant of the horizontal pulls of the span tackles of the derricks under load, plus any cargo runners that may be led to the mast head.



**2707** The lengths of masts and posts are to be measured from the uppermost deck through which they pass to the mean intersection of the span and stay lines of action. (For this purpose, where a mast or post is supported by a deckhouse, the house top is to be regarded as a deck unless the house is specifically designed to give no effective support to the mast or post in both the transverse and fore and aft directions.)

#### Mast Scantlings

**2708** The diameter and thickness of the mast or post at deck level is to be derived from Table D 27.1 for the appropriate resultant pull of span tackles and mast length. The diameter and thickness of the mast or post at the hounds are assumed to be 85 per cent of the Table values.

#### Stay Sizes

**2709** Stay sizes are to be determined by means of two factors; "B" and "C".

Factor B is to be obtained from Table D 27.1 for the appropriate mast length and resultant pull of span tackles.

Factor C is to be obtained from Table D 27.2.

In Table D 27.2 the symbols are as follows:—

$h$  is the horizontal spacing of the mast-head stay eyeplate and the deck (or bulwark) stay eyeplate.  $h$  may vary for each stay (see Fig. D 27.1 where varying values of  $h$  are shown as  $h_1$ ,  $h_2$ ,  $h_3$  and  $h_4$ ).

$x$  is the horizontal distance from the deck (or bulwark) stay eyeplate to the line of action of the derrick boom (or mean line of action of the derrick booms if more than one will be in use).  $x$  may vary for each stay see Fig. D 27.1.

In Fig. D 27.1 the derrick boom is shown hung on the mast. Where a boom is hung on a crosstree of normal length, the "line of action" of the boom should be transferred to the centre of the mast before measuring  $x$  and  $h$  values.

If the mast's stays are attached to a point a short way along a crosstree (see 2718), the line of action of the stays should be transferred to the centre of the mast before measuring  $x$  and  $h$ .

Where the stays are attached to the end of crosstrees or where derrick span blocks are attached to crosstrees at a much greater than normal distance from the mast, then a full stress calculation will be necessary.

$v$  is the vertical spacing of the mast-head stay eyeplate and the deck (or bulwark) stay eyeplate.  $v$  may vary

These stays are not included in the calculation for this boom position as they make angles greater than  $90^\circ$  to the line of action of the boom

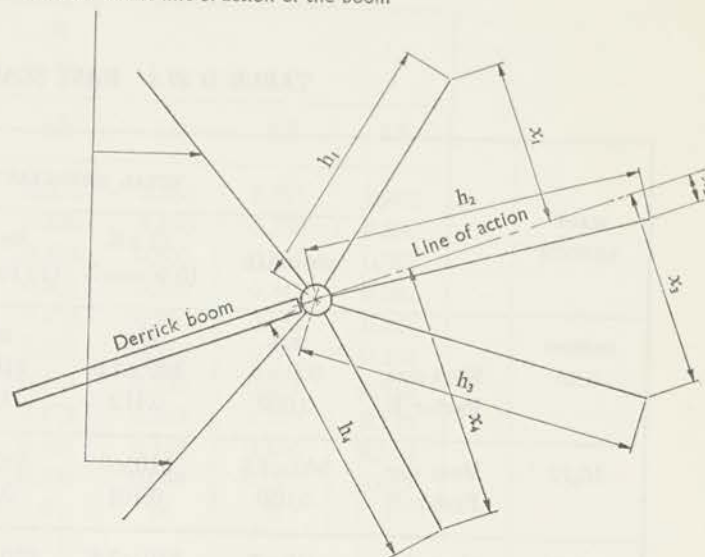


FIG. D 27.1

for each stay due to variations in deck or bulwark levels, but Table D 27.1 is only applicable if the stays are attached to the mast at or near to the same level as the span tackle.

The values of  $\frac{x}{h}$  and  $\frac{h}{v}$  are to be used to obtain the appropriate value of factor C for each stay.

**2710** The values of factor C for all stays are to be added and the required metallic cross-sectional area of each stay is to be obtained from the following formula:—

$$\text{Area} = 645 A_w = 645 \frac{\text{Factor B}}{\text{Sum of Factors C}} \text{ mm}^2$$

This formula assumes that all stays are the same size and construction and that the heights  $v$  in no case exceed the mast length by more than 1.25 m.

If  $v$ , for any particular stay, does exceed the mast length by more than 1.25 m then the metallic cross-sectional area for that particular stay is to be increased in the ratio of  $\frac{v}{\text{mast length}}$ .

**2711** The size of stays equivalent to various values of  $A_w$  are given in Table D 27.3 for representative wire ropes, but exact values provided by the manufacturer of any particular rope are acceptable.

TABLE D 27.1 MAST SCANTLINGS AND FACTOR "B"

MAST LENGTH		TOTAL RESULTANT OF HORIZONTAL PULLS OF SPAN TACKLES						
		NO LOAD	49 kN (5 tonne-f)	98 kN (10 tonne-f)	147 kN (15 tonne-f)	196 kN (20 tonne-f)	245 kN (25 tonne-f)	294 kN (30 tonne-f)
metres		mm	mm	mm	mm	mm	mm	mm
9,25	Mast size Factor B	300×6 0,030	460×7,5 0,112	510×9 0,265	570×12 0,439	630×12,5 0,680	700×12,5 0,939	760×12,5 1,246
10,75	Mast size Factor B	360×6,5 0,030	510×8 0,101	570×10 0,243	630×11,5 0,430	700×12 0,639	760×12 0,885	810×13 1,137
12,25	Mast size Factor B	410×7 0,030	560×7,5 0,093	620×10,5 0,230	670×12 0,394	740×12,5 0,591	790×13,5 0,799	840×14 1,018
13,75	Mast size Factor B	460×7,5 0,030	580×8 0,082	650×10,5 0,217	710×12 0,368	760×13 0,538	810×14 0,730	860×14,5 0,927
15,25	Mast size Factor B	510×8 0,030	610×9,5 0,072	690×11 0,202	740×13 0,338	790×14 0,497	840×14,5 0,674	900×15,5 0,854
16,75	Mast size Factor B	560×8,5 0,030	660×9,5 0,068	720×11 0,190	790×12,5 0,328	840×14 0,478	890×14,5 0,648	940×15,5 0,824
18,25	Mast size Factor B	610×9 0,030	710×10 0,059	760×11 0,180	810×13,5 0,304	860×15 0,443	910×15,5 0,600	970×16 0,774

NOTE. When two sets of derricks with differing span tackle pulls are hung one forward and one aft of a mast, it will be possible to use Table D 27.1 only if the difference in the span pull resultants does not exceed 20 per cent of the larger pull. Within these limits the mast size chosen should be the smaller of the differing scantlings derived from the Table, but the values of factor B should be those appropriate to the span resultant in each case. Where the span resultants vary by more than 20 per cent, a full stress calculation should be made, see 2701.

Excessively stiff masts, i.e. masts in which the inertia is greater than that shown in the Table, should not be fitted since they will deflect less than assumed and the stays will not take their correct proportion of the load. Small reductions in mast stiffness, relative to the Table values, can be accepted provided the modulus deficiency is proportionally less than that of the inertia.



TABLE D 27.2 STAY EFFICIENCY FACTOR "C"

$\frac{x}{h}$	$\frac{h}{v}$						
	0,6	0,7	0,8	0,9	1,0	1,2	1,5
0	0,227	0,269	0,308	0,333	0,353	0,377	0,384
0,1	0,225	0,267	0,304	0,330	0,350	0,372	0,380
0,2	0,217	0,258	0,294	0,318	0,338	0,361	0,367
0,3	0,206	0,243	0,278	0,301	0,320	0,341	0,347
0,4	0,189	0,225	0,257	0,278	0,296	0,315	0,321
0,5	0,171	0,202	0,231	0,250	0,265	0,283	0,288
0,6	0,145	0,172	0,196	0,212	0,225	0,241	0,245
0,7	0,117	0,139	0,159	0,172	0,183	0,195	0,198
0,8	0,082	0,097	0,111	0,120	0,128	0,136	0,139
0,9	0,044	0,052	0,059	0,064	0,068	0,071	0,073
1,0	0	0	0	0	0	0	0

TABLE D 27.3 WIRE ROPE DIAMETERS FOR VARYING VALUES OF  $A_w$ 

DIA. mm	CONSTRUCTION			
	6×7	6×19	7×7	7×19
	$A_w$	$A_w$	$A_w$	$A_w$
8	0,037	0,037	—	—
9	0,045	0,050	—	—
10	0,057	0,059	0,067	—
11	0,069	0,069	0,081	—
12	0,088	0,089	0,104	—
14	0,116	0,114	0,137	0,135
16	0,150	0,154	0,176	0,184
18	0,187	0,185	0,220	0,220
20	0,240	0,236	0,283	0,282
22	0,286	0,275	0,338	0,326
24	0,338	0,336	0,396	0,386
26	0,393	0,402	0,462	0,481
28	0,466	0,452	0,550	0,541
32	0,598	0,587	0,703	0,701
36	0,769	0,738	0,903	0,881
40	0,936	0,943	—	1,127
44	—	1,136	—	1,352
48	—	1,361	—	1,604
52	—	1,569	—	1,872
56	—	1,812	—	2,160

**Stress Calculations—Unstayed Masts and Posts**

**2712** Where only one derrick is to be loaded at one time (e.g. a heavy derrick on the ship's centreline), or where two derricks may be loaded at the same time but while working different hatches, the worst stresses, for rigs of normal design, can be assumed to occur with the derrick boom or booms swung outboard (on the same side of the ship if two booms are concerned).

Where two derricks are designed to work one hatch simultaneously, the worst stresses, for masts of circular section, can be assumed to occur with both booms plumb that hatch.

**2713** The reaction of a derrick heel is to be ignored when calculating the bending moment in a mast or post, unless the gooseneck, trunnion or other similar heel fitting is attached to the mast or post, or to a lower crosstree or outrigger, which is wholly supported by the mast or post.

**2714** The bending moment acting at any particular point is the sum of:—

- (a) Each force component acting perpendicularly to the mast or post, and parallel to the plane in which the mast or post will bend, multiplied by the distance (measured parallel to the mast or post) of that force above the point under consideration.
- (b) Each force component acting parallel to the mast or post multiplied by the distance (measured perpendicularly to a plane through the neutral axis of that mast or post) of that force from the plane through the neutral axis.

**2715** The bending stress,  $f_B$ , on the mast or derrick post at each position under consideration, is to be calculated from the formula:—

$$f_B = \frac{M_m y}{I_m} \text{ N/mm}^2 (\text{kgf/mm}^2)$$

where  $M_m$  = bending moment derived as specified in 2714, in N mm (kgf mm),

$I_m$  = moment of inertia of the mast at the height under consideration, in  $\text{mm}^4$ ,

$y$  = the distance from the neutral axis of the mast to the extreme outer surface at the height under consideration, in mm.

**2716** The direct compressive stress acting on the mast is to be calculated by summing all the vertical components of span gear, derrick thrust, etc., as applicable, and the weight of the topmast and crosstrees if fitted, and dividing the total by the cross-sectional area of the mast or post at the position under consideration.

The weight of the mast or post tube itself need not be included.

**2717** The sum of bending and direct stresses derived from 2715 and 2716 is not at any point to exceed  $0,55 Y$  or  $0,35 U + 0,005 Y$  whichever is the least, where the S.W.L. of none of the derrick booms exceed 10 tonnes. Where the S.W.L. of one or more derricks exceeds 10 tonnes then the stress may increase by  $0,010 Y$  or by  $0,007 U$ , whichever is the least, for each 4 tonne increase in the S.W.L. of the derrick with the highest S.W.L., where  $Y$  = specified minimum yield stress or 0,5 per cent proof stress and  $U$  = specified minimum tensile strength plus one-half of the specified range of tensile strength. For ordinary shipbuilding mild steel  $Y$  may be taken as  $245 \text{ N/mm}^2$  ( $25 \text{ kgf/mm}^2$ ) and  $U$  as  $450 \text{ N/mm}^2$  ( $46 \text{ kgf/mm}^2$ ).

The stresses in crosstrees, outriggers, and similar items are to be derived as for masts but using the highest S.W.L. of any derrick actually supported by the crosstree or outrigger.

**2718** The effect of torque need not be included in calculating the stresses in masts of normal design, unless the span tackle eyeplate pins to which the derricks are attached to crosstrees or outriggers, are at a distance from the mast centreline exceeding  $\frac{D^2}{25,4 \text{ S.W.L.}}$  mm where  $D$  is the mast diameter at half-height, in mm. S.W.L. is the highest safe working load of any derrick supported by the crosstree or outrigger in question, in tonnes.

When torque is taken into account it is to be taken as:—

$T$  = horizontal component of span tension  $\times$  distance from span eye to centreline of mast or post in N mm (kgf mm).

Shear stress is to be taken as  $q = \frac{T}{2At}$ , where  $A$  is the total area enclosed by the outer surface of the mast or post (for circular masts,  $A = \frac{\pi (\text{diameter})^2}{4} \text{ mm}^2$ ) and  $t$  is the wall thickness of the mast or tube, in mm.

The total stress in the mast or post is:—

$$f_t = 0,5 (f_m + \sqrt{(f_m)^2 + 4q^2}) \text{ N/mm}^2 (\text{kgf/mm}^2)$$

where  $f_m$  is the stress value derived from 2717.

**2719** The wall thickness, in mm, of oval or circular masts and posts is not to be less than:—

$$\frac{FD \sqrt{KY}}{350 + 2 \times \text{S.W.L.}} \quad \text{or} \quad \frac{FD}{100} \quad (1)$$

whichever is the greater,



where  $D$  = maximum outside diameter of the mast at corresponding height above the deck, in mm,

$$F = \sqrt{\frac{\text{Actual calculated stress}}{\text{Maximum permitted stress}}}$$

$$K = 0,102 (1,00),$$

$$Y = \text{yield stress, in N/mm}^2 (\text{kgf/mm}^2),$$

S.W.L. = maximum safe working load of any derrick supported by the mast, in tonnes.

The wall thickness, in mm, of unstiffened flat sides of masts or posts, with one or more flat sides, is not to be less than:—

$$\frac{FW \sqrt{KY}}{200 + 2 \times \text{S.W.L.}} \quad \text{or} \quad \frac{FW}{60} \quad (2)$$

whichever is the greater,

where  $K$ ,  $Y$ ,  $F$ , and  $\text{S.W.L.}$  are as defined above and  $W$  is the width, in mm, of the flat side at that height or 60 per cent of the width of the mast at that height, measured parallel to the flat side, whichever is the greater.

Where masts are constructed of a combination of curved and flat plates, e.g. curved sides and flat front and back, the value  $\frac{FW}{60}$  may be used in determining the minimum thickness if this is more favourable than  $\frac{FD}{100}$  for the curved plates.

Where flat sides of masts or posts are fitted with vertical stiffeners effectively restrained against tripping, then the values of  $W$  used in the formulæ may be taken as the stiffener spacing.

Attention is drawn to the fact that this paragraph is designed to prevent local buckling of the mast plating under compression loading, assuming some local initial unfairness in the plating, and if stiffeners are fitted to permit reductions in plate thicknesses, then they should not be liable to instability under end loading.

#### Fittings and Details

2720 Masts and derrick posts are to be increased in thickness at the heel and decks and other points of support, and are to be suitably strengthened to take any concentrated loads which may be expected to occur in way of derrick fittings, crosstrees and ventilation openings. They should normally be attached to at least two decks other than the tops of winch houses and small deckhouses of a type giving no effective support, but need not be attached to more than two decks or one deck and the top of a substantial house.

The heels of masts and derrick posts are to be effectively supported.

2721 The design and construction of masts, posts and fittings is to be such as to reduce the likelihood of water collecting in inaccessible parts of the structure.

2722 For lightning conductors, see M 19.

#### Workmanship

2723 Smithwork should be of a material not liable to work hardening or ageing to a significant degree during normal use.

Rimming steel should not be used.

Where fittings are flame cut from solid material they are to be annealed after cutting and all flame cut faces are to be ground if necessary to give a smooth finish to avoid stress raisers.

#### Crosstrees

2724 Where outriggers or crosstrees at mast-heads are of unusual spread or where stays are attached to the crosstrees well clear of the mast, the scantlings of the mast and rigging will be specially considered.

The stresses in crosstrees should not normally exceed 55 per cent of the yield stress of the material or (for items under compression) of the crippling stress of that item.

#### Section 28

#### BULWARKS, FREEING PORTS, SCUPPERS AND SANITARY DISCHARGES AND SIDE SCUTTLES

##### Bulwarks

2801 The height of plate bulwarks on exposed parts of freeboard and superstructure decks, measured above sheathing if fitted, is to be at least 1,0 m except that where this height would interfere with the normal operation of the ship a lesser height may be approved.

2802 Plate bulwarks are to be stiffened by a strong rail section and supported by stays from the deck. The spacing of these stays forward of 0,07L from the fore perpendicular is not to be more than 1,2 m on Types "A" "B-60" and "B-100" ships and not more than 1,83 m on other types. Elsewhere, bulwark stays are not to be more than 1,83 m apart. Where bulwarks are cut to form a gangway or other opening, stays of increased strength are to be fitted at the ends of the openings. Bulwarks are to be adequately strengthened in way of eyeplates for cargo gear and in way of mooring pipes the plating is to be doubled or increased in thickness and adequately stiffened.



**2803** Bulwarks should not be cut for gangway or other openings near the breaks of superstructures and are also to be arranged to ensure their freedom from main structural stresses. *See D 509.*

#### Freeing Ports

**2804** Where bulwarks on the weather portions of freeboard or superstructure decks form wells, ample provision is to be made for rapidly freeing the decks of large quantities of water by means of freeing ports and also for draining them.

**2805** The minimum freeing port area on each side of the ship, for each well on the freeboard deck (including raised quarter decks), where the sheer in way of the well is standard or greater than standard, is to be as given by the following formulæ. *See also 2807.*

- (a) Where the length ( $l$ ) of the bulwark in the well is 20 m or less:—

$$\text{Area required} = 0,7 + 0,035 l \text{ m}^2$$

- (b) Where the length ( $l$ ) exceeds 20 m:—

$$\text{Area required} = 0,07 l \text{ m}^2$$

$l$  need not be taken greater than 0,7L

If the average height of the bulwark exceeds 1,2 m or is less than 0,9 m the freeing port area is to be increased or decreased respectively by 0,004 m<sup>2</sup> per metre of length of well for each 0,1 m difference in height from Rule.

The minimum freeing port area for each well on superstructure decks is to be half the area given by the above.

Type "B" ships with reduced freeboards will require to have freeing port area greater than given above.

**2806** In ships with no sheer the freeing port area is to be increased by 50 per cent. Where the sheer is less than the standard, the percentage is to be obtained by interpolation.

**2807** Where ships are fitted on the freeboard deck with continuous trunk or continuous hatchside coaming in association with bulwarks, the minimum area of freeing port openings is to be not less than 20 per cent of the total area of bulwarks when the width of trunk or hatch is 0,4B or less and not less than 10 per cent of the total area of bulwarks when the width of the hatch is 0,75B or more, with intermediate values by interpolation.

**2808** Adequate provision is to be made for freeing water from superstructures which are open at either or both ends and from all other decks within open or partially open spaces in which water may be shipped and contained.

**2809** Two-thirds of the freeing port area required is to be provided in the half of the well nearest to the lowest point of the sheer curve.

**2810** The lower edges of freeing ports are to be as near to the deck as practicable and the openings are to be protected by rails spaced approximately 230 mm apart. If hinged shutters are fitted to freeing ports ample clearance is to be provided to prevent jamming, and if securing appliances are fitted these appliances are to be of approved construction. Hinges are to have pins or bearings of non-corrodible material.

#### Scuppers and Sanitary Discharges

**2811** Scuppers sufficient in number and size to provide effective drainage are to be fitted in all decks.

**2812** In ships over 150 m in length, scupper openings are not to be cut in the sheerstrake above deck level within 0,5L amidships, and in no case in way of discontinuities such as breaks of superstructures. *See D 509.*

When scuppers or discharges are cut in the shell or superstructure sides compensation may require to be fitted.

**2813** Scuppers and discharges which drain spaces below the freeboard deck or spaces within intact superstructures or deckhouses on the freeboard deck fitted with efficient weathertight doors, may be led to the bilges in the case of scuppers or to suitable sanitary tanks in the case of sanitary pipes. Alternatively, they may be led overboard provided the spaces drained are above the load waterline, and the pipes are fitted with efficient and accessible means of preventing water from passing inboard. *See 2814.*

**2814** In general, each separate overboard discharge is to be fitted with a screw-down non-return valve capable of being operated from a position always accessible and above the freeboard deck. An indicator is to be fitted at the control position showing whether the valve is open or closed.

Where, however, the vertical distance from the summer load waterline to the inboard end of the discharge pipe exceeds 0,01L the discharge may be fitted with two automatic non-return valves without positive means of closing, instead of the screw-down non-return valve, provided the inboard valve is always accessible for examination under service conditions.

Where the vertical distance from the summer load waterline to the inboard end of the discharge pipe exceeds 0,02L, consideration will be given to proposals for fitting a single automatic non-return valve without positive means of closing.

**2815** Scuppers and discharge pipes originating at any level, which penetrate the shell either more than 450 mm



below the freeboard deck or less than 600 mm above the summer load waterline are to be fitted with an automatic non-return valve at the shell.

This valve, unless required by 2813, may be omitted provided the pipe thickness is not less than:—

$$\frac{\text{Diameter of pipe in mm}}{24} + 6,5 \text{ mm}$$

but need not exceed 12,5 mm, unless a greater thickness is required by 2816.

**2816** Scuppers and discharge pipes should not normally pass through fuel oil or cargo oil tanks. Where scuppers and discharge pipes pass, unavoidably, through fuel oil or cargo oil tanks, and are led through the shell within the tanks, the thickness of the piping should be at least the same thickness as Rule shell plating in way derived from D 505 or D 4305, but need not exceed 19 mm.

The pipes should be tested in accordance with D 1934 and D 5205. Piping within the tanks should be adequately supported.

If a non-return valve is required by 2813, this should preferably be fitted as close as possible to the point of entry of the pipe into the tank. If fitted below the freeboard deck the valve should be capable of being controlled from an easily accessible position above the freeboard deck. Local control is also to be arranged, unless the valve is inaccessible. An indicator is to be fitted at the control position showing whether the valve is open or closed.

**2817** Scuppers draining weather decks and spaces within superstructures or deckhouses not fitted with efficient weathertight doors are to be led overboard.

**2818** Plans showing the arrangement of scuppers for draining refrigerated cargo compartments are to be submitted for consideration.

#### Materials for Valves, Fittings and Pipes

**2819** All valves required by 2814, and shell fittings where no valves are required, are to be of steel, bronze or other approved ductile material; ordinary cast iron is not acceptable. Material submitted for approval is to have an elongation not less than 12 per cent on a gauge length of  $5,65\sqrt{S_0}$ , where  $S_0$  is the actual cross-sectional area of the test piece.

All these items, if made of steel or other approved material with low corrosion resistance, are to be suitably protected against wastage.

The lengths of pipe attached to the required valves or elbow pieces are to be of galvanized steel of standard steam

pipe quality or other equivalent approved material. *See also F 706.*

#### Protection of Pipes and Valves

**2820** In all cargo spaces and other areas where damage might be likely, all scuppers and discharges including their valves, controls and indicators are to be well protected. This protection is to be of steel in bulk cargo spaces or their equivalent, and also in areas where contact with large containers, fork lift trucks or similar items is a possibility.

#### Side Scuttles

**2821** Side scuttles, together with their glasses if fitted, and deadlights, are to be of approved design and of approved material other than ordinary cast iron. They are to be metal framed and glasses are to be retained by a metal glazing bead.

**2822** Side scuttles to spaces below the freeboard deck or to spaces within enclosed superstructures are to be fitted with efficient inside deadlights permanently attached and capable of being closed and secured watertight.

**2823** No side scuttle is to be fitted in a position so that its sill is below a line drawn parallel to the freeboard deck at side and having its lowest point 2,5 per cent of the breadth B above the load waterline of 500 mm whichever is the greater distance.

**2824** In passenger ships, the position and construction of the side scuttles will be specially considered. (*See also F 813.*)

### Section 29

#### VENTILATION, AIR PIPES AND SOUNDING PIPES

##### Ventilator Coamings

**2901** The minimum height of ventilator coamings above the upper surface of decks exposed to the weather, measured above sheathing if fitted, is to be as follows:—

Ventilators situated in position 1 (*see D 2605*)  
900 mm,

Ventilators situated in position 2 (*see D 2605*)  
760 mm.

Where it is intended to fit patent ventilators the minimum height of coaming will be specially considered.

**2902** Ventilator coamings having a height greater than 900 mm are to be specially supported.



2903 The thickness of steel ventilator coamings is to be not less than:—

$$5,5 + \frac{\delta}{100} \text{ mm}$$

where  $\delta$  is the internal diameter of the coaming, in mm. The thickness need not exceed 10 mm, but is not to be less than 7,5 mm.

2904 The deck plating in way of ventilator coamings is to be efficiently stiffened.

2905 All ventilator coamings are to be provided with strong plugs and canvas covers or equally efficient weather-tight closing appliances unless (a) the height of the coaming is greater than 4,5 m where 2901 requires a minimum height of 900 mm, or (b) the height of the coaming is greater than 2,3 m where 2901 requires a minimum height of 760 mm.

These closing appliances are to be either permanently attached to the ventilator coaming or, in the case of ships 100 m or more in length, may be stowed in a convenient and accessible position close to the coaming for which they are intended to be used.

2906 In particularly exposed positions the heights, scantlings and/or supports of ventilator coamings may be required to be suitably increased above the values given above.

#### Positioning of Ventilators

2907 Special care is to be taken when designing and positioning ventilator openings and coamings, particularly in the region of the forward end of superstructures and other points of high stress.

Within 0,5L amidships, any ventilation openings should be included when calculating whether compensation is required by D 408.

Where practicable, ventilators should be sited clear of highly stressed parts of the structure. In general, ventilation openings should not be cut in deck girders within 1,5 m of pillars or the girder endings.

See also D 411 and D 412.

#### Minor Ventilators

2908 Mushroom, gooseneck and other similar minor ventilators are to be strongly constructed and efficiently secured to the deck plating.

#### Fire Precautions

2909 For passenger ships, see F 815 to F 817.

For cargo ships, see F 1004.

#### Air and Sounding Pipes

2910 Air and sounding pipes are to comply with the requirements of Chapter E.

2911 The height of air pipes from the upper surface of decks exposed to the weather, to the point where water may have access below is not normally to be less than:—

On the freeboard deck .... 760 mm,

On superstructure decks .... 450 mm.

These heights are to be measured above sheathing, where fitted.

Lower heights may be approved in cases where these are essential for the working of the ship, provided the design and arrangements are otherwise satisfactory.

2912 All openings of air and sounding pipes are to be provided with permanently attached satisfactory means of closing to prevent the free entry of water.

2913 Striking plates of suitable thickness, or their equivalent, are to be fitted under all sounding pipes.

2914 Air and sounding pipes are to be well protected in all spaces. This protection is to be of steel in bulk cargo spaces or their equivalent, and also in areas where contact with large containers, wheeled vehicles or similar items is a possibility.

#### Section 32

#### WELDING

##### General

3201 Where electric arc welding is to be used for the main structure, the arrangement of plating, disposition and type of joints, together with the proposed sequence of prefabrication, assembly and welding are to be submitted for approval. The extent to which automatic welding (whether deep penetration or otherwise) is to be used should be indicated.

Details of welded connections of main structural members with type and size of welds are to be clearly indicated on the plans submitted for approval.

The approved arrangements, sequences and procedures are not to be departed from without approval.

3202 The structural arrangements are to be such as will allow easy access for welding operations and facilitate the use of downhand welding wherever possible.

The type and disposition of connections and sequences of welding are to be so planned that any restraint during welding operations is reduced to a minimum.



**3203** The electrodes used are to be approved by the Committee and are to be suitable for the type of joint and grade of steel as follows:—

Grade 1—for Grade A steel,

Grade 2—for Grades A, B or D steel,

Grade 3—for Grades A, B, D or E steel.

When joining two different grades of steel of the same tensile properties, electrodes suitable for the lower grade are generally acceptable, except at discontinuities or other points of stress concentration. The requirements for electrodes are given in P 11.

#### Primers and Coatings

**3204** Where primers are applied over areas which will subsequently be welded, they are to be of a quality accepted by the Society as having no deleterious effect on the finished weld.

#### Inspection

**3205** Effective arrangements are to be provided for the inspection of finished welds in order to ensure that all welding has been satisfactorily completed.

Visual inspection may require to be supplemented by other forms of non-destructive crack or flaw detection methods for the examination of important structural welds. The extent of such examination is to be to the Surveyor's satisfaction but particular attention should be paid to the following locations:—

- (a) Junction and crossings of seams and butts in strength deck, sheerstrake, side and bottom shell within 0,4L amidships.
- (b) Butts of keel plating and rounded sheerstrake within 0,4L amidships.
- (c) Insert plates in way of hatch openings in the strength deck.

A system of radiographic examination should be used wherever practicable and where this is available the Surveyors are to collaborate with the Builders in this system of inspection. (See also 3219 (f) for higher tensile steel.)

All defective sections of welds are to be cut out, carefully re-welded and re-examined.

**3206** Alternative proposals for methods of welding considered by the Committee to be equivalent to those set forth in the Rules will be accepted.

#### Joints and Connections

**3207 BUTT WELDS.** In general, the edges of plates to be joined by manual welding are to be bevelled on one

side or on both sides of the plates to provide an included angle of from 50 to 60 degrees.

Where it is desired to adopt other forms of edge preparation full details are to be submitted for approval.

A back sealing run is to be applied, after suitable back gouging, to all butt welds where main welding is carried out from one side only, unless the welding process has been specially approved for use without a back run.

**3208 FILLET WELDS.** The dimensions of fillet welds for structural connections are to be as required by Table D 32.1 and associated Notes.

The weld throat thickness is a function of plate thickness and weld factor. The leg length of welds is not to be less than  $\sqrt{2}$  times the derived throat thickness.

**3209 TEE CONNECTIONS.** The throat thickness of the fillets is generally to be governed by the thickness of the thinner of the two parts being joined.

Where the difference between the thicknesses of the parts to be joined is considerable, the size of the fillet will be specially considered (see Table D 32.1, Note 1, for slab type longitudinals).

Tee connections should be made by fillets on both sides of the abutting plate. Where the abutting plate is bevelled a sealing run should be applied on the reverse side.

**3210 INTERMITTENT FILLETS.** Details of staggered and chain intermittent welds are shown in Fig. D 32.1. The length of intermittent welds is to be measured over the correctly proportioned fillet, clear of end craters.

Intermittent welds are to be doubled at the ends of all structural members, and the welding is to be carried round the ends of brackets, lugs, etc.

**3211 SCALLOPS AND NOTCHES.** The details of scalloped construction are given in Fig. D 32.1. All scallops are to have well rounded corners and smooth edges, and the welding is to be carried round the ends of all lugs and scallop edges. Scallops are not to be cut in way of the toes of bracket connections or at other parts where stress concentrations may develop.

Scallops in side frames, longitudinals and stiffeners are to be omitted for at least 230 mm on each side of the intersection with a primary supporting member.

Notches in primary supporting members are not to be larger than necessary, and are to have well rounded corners and smooth edges. When notches occur at points where stress concentration may develop, such as adjacent to the toes of brackets, a welded collar or equivalent reinforcement is to be fitted.



**TABLE D 32.1** (see continuation)  
**DETAILS OF VARIOUS FILLET WELD CONNECTIONS**

ITEM	WELD FACTOR	REMARKS
<b>DOUBLE BOTTOMS AND HOPPER SIDE TANKS</b>		
Centre girder to keel ... .. {	0,35	if watertight
	0,26	elsewhere
Centre girder to inner bottom ... {	0,35	if watertight
	0,26	in engine space and under thrust blocks (no scallops)
Non-watertight floors to centre girder ... {	0,21	elsewhere (no scallops)
	0,26	under engine, thrust and boiler bearers
Non-watertight floors to margin plate ... {	0,12	elsewhere
	To depend on design	generally 0,44 in panting region and 0,35 elsewhere
Non-watertight floors to side girders ... {	0,12	
	0,21	in way of strengthened bottom forward (see D 1007)
Non-watertight floors, bracket floors and non-watertight side girders to shell and inner bottom ... {	0,21	to inner bottom under engine and thrust bearers
	0,26	for 2 spaces at ends of floors (longitudinal framing)
	0,12	elsewhere (longitudinal framing)
	0,10	elsewhere (transverse framing)
Longitudinal foundation girders under main diesel engines ... .. {	—	in general, full penetration welding is required
Bottom frames to shell, floors and bracket floors ... .. {	0,21	in way of strengthened bottom forward (see D 1007)
	0,10	elsewhere
Reversed frames to bracket floors and inner bottom ... .. {	0,21	under engine and thrust bearers
	0,10	elsewhere
Tank side brackets to inner bottom and margin plate ... .. {	0,44	in panting region
	0,35	elsewhere—generally
Inner bottom or margin plate to shell ...	0,35	
Boundaries of watertight and oiltight floors, side girders or double bottom wells ...	0,35	
Stiffeners of watertight and oiltight floors, side girders or double bottom wells ...	0,14	
Bottom longitudinals to shell and floors ... {	0,12	for 0,25L forward (see Note 1 and Note 6)
	0,10	elsewhere (see Note 1 and Note 6)
Bottom longitudinals of the flat bar or plate type to shell ... .. {	0,25	but need not exceed 5,5 mm hand, or 4,5 mm automatic. See also Note 1
	Continuous weld	
Inner bottom longitudinals to inner bottom... {	0,12	under ore holds (see Note 1 and Note 6)
	0,10	elsewhere (see Note 1 and Note 6)
Hopper tank and wing tank longitudinals ...	0,12	see Note 1 and Note 6
Frames to tank side brackets ... .. {	—	see Note 7
<b>LONGITUDINAL AND TRANSVERSE FRAMING</b>		
Hold frames and longitudinals (including ice frames) to shell ... .. {	0,10	
	0,12	in panting region
	—	continuous in way of beam knees and tank side brackets. See Note 7
Frames in machinery spaces ... .. {	0,12	
'Tween deck frames to shell ... .. {	0,10	
	0,21	in way of strengthened bottom forward (see D 1007)
Bottom frames to shell, floors and bracket floors ... .. {	0,10	elsewhere



TABLE D 32.1 (continued)

ITEM	WELD FACTOR	REMARKS
LONGITUDINAL AND TRANSVERSE FRAMING (continued)		
Bottom longitudinals of the flat bar or plate type to shell ... ..	0,17 0,12 0,10 —	(as in Double Bottoms) generally to shell. Up to 0,35 when highly loaded. Continuous in way of end brackets. to face bars or face plates of area greater than 30 cm <sup>2</sup> elsewhere see Note 7
Web frames or side transverses supporting longitudinals ... ..		
For welding of knees and brackets ... ..		
DEEP TANKS AND BUNKERS		
Bulkhead boundary connections ... ..	0,39 0,35 0,44 0,12 — 0,26 0,14 0,26 0,12 0,10 0,21 0,12 0,10 0,12	at bottom and bilge (see Note 6) at deck and side (see Note 6) at ends of swedges (see D 1817) see D 1817 and D 1910 see Note 7, D 1817 and D 1910 in way of end brackets clear of end brackets generally continuous face bar area greater than 30 cm <sup>2</sup> face bar area not exceeding 30 cm <sup>2</sup> in panting region elsewhere
Frames, longitudinals and stiffeners ... ..		
Stiffener brackets ... ..		
Horizontal girders to shell and bulkheads ... ..		
Horizontal girders to girder brackets ... ..	0,12 0,10 0,21 0,12	face bar area greater than 30 cm <sup>2</sup> face bar area not exceeding 30 cm <sup>2</sup> in panting region elsewhere
Girder webs to face bars ... ..		
Open floors to shell ... ..		
Boundaries of perforated flats and wash bulkheads ... ..		
Beams at crown of tanks ... ..	0,10 0,12	see Note 6
CARGO OIL TANKS		
Side frames to shell ... ..	0,12	see Table D 32.2 for a distance either side of the bulkhead equal to 0,30 × spacing of transverses when longitudinals are continuous in forward 0,25L (except at ends of span, where as above) elsewhere continuous but need not exceed 5,5 mm hand or 4,5 mm automatic (see also Note 1)
Web frames and side transverses ... ..	0,35 0,12 0,22 0,12 0,25	
Bottom longitudinals to shell (except as below)		
Bottom longitudinals of flat bar type to shell		
Side longitudinals to shell ... ..	0,11 0,35	over 4,6 m below top of tank for a distance either side of bulkhead equal to 0,25 × spacing of transverse. This increase is not necessary above 7,6 m below top of tank when longitudinals are continuous
Deck longitudinals to deck plating, except as below ... ..	0,11	continuous weld—but need not exceed 5,5 mm hand or 4,5 mm automatic (see also Note 1)
Deck longitudinals of flat bar type to deck plating ... ..	0,25	

TABLE D 32.1 (continued)

ITEM	WELD FACTOR	REMARKS
<b>CARGO OIL TANKS (continued)</b>		
Longitudinals to stiffening bars on primary supporting members ... ..		see Table D 32.4
Intercostal bottom side girders to shell ...		as for bottom longitudinals
Intercostal deck side girders to deck plating ...		as for deck longitudinals
Face bar of intercostal bottom and deck side girders to respective web plates ... ..	0,12	
Bottom frames to shell and floors forward ...	0,22	
Floors to centre girder or centreline bulkhead forward ... ..	0,44	
Bottom transverses to shell ... ..	}	see Table D 32.2
Side transverses to shell ... ..		
Deck transverses to deck plating ... ..		
Web frames to shell ... ..		
Vertical webs on longitudinal and transverse bulkheads ... ..		
Stringers to shell ... ..	}	
Horizontal girders to oiltight bulkheads ...		
Bottom transverses to longitudinal bulkheads and centreline girder ... ..		
Deck transverses to longitudinal bulkheads and centreline girder ... ..		
	0,44	
	0,35	
<b>OILTIGHT TRANSVERSE AND LONGITUDINAL BULKHEADS</b>		
Vertical stiffeners ... ..	0,12	
	0,11	on longitudinal bulkheads
	0,35	on longitudinal bulkheads for a distance either side of bulkhead equal to $0,25 \times$ spacing of transverses. This increase is not necessary if longitudinals are continuous through bulkhead
Horizontal stiffeners ... ..	0,11	on transverse bulkheads up to 5,5 m below the top of the tank
	0,13	on transverse bulkheads over 5,5 m below the top of the tank
	0,44	longitudinal bulkheads to bottom or deck (see Note 5)
Boundaries ... ..	0,44	transverse bulkheads to shell at bottom or bilge
	0,35	transverse bulkheads to shell at side or to deck, or longitudinal bulkheads
Vertical webs ... ..	}	see Table D 32.2
Horizontal girders ... ..		
End brackets of all primary supporting members ... ..	0,44	
Brackets at head of side frames ... ..		see Table D 32.3
Side frames to bilge brackets ... ..		to depend on arrangements adopted generally but to depend on design
End connections of longitudinals ... ..	0,44	
Brackets at ends of stiffeners on transverse bulkheads ... ..		to depend on end connections of longitudinals
Tripping brackets ... ..	0,11	
Docking brackets ... ..	0,13	
Stiffening of primary supporting members ...	0,10	see also Table D 32.4



TABLE D 32.1 (continued)

ITEM	WELD FACTOR	REMARKS
WATERTIGHT BULKHEADS, FLATS AND TUNNELS		
Bulkhead boundary connections ... ..	0,35	if thickness does not exceed 6 mm <i>see</i> Note 2 generally ( <i>see</i> Note 6) when supporting pillars above as required by D 1817 <i>see</i> Note 7 and D 1817
Stiffeners ... ..	0,10	
Stiffeners used as pillars ... ..	0,14	
Ends of unbracketed stiffeners ... ..	0,44	
Brackets and lugs ... ..	—	
DECKHOUSES		
Connections to deck ... ..	0,35	<i>see</i> Note 7 and Table D 17.4
Stiffeners ... ..	0,10	
Stiffener end connections ... ..	—	
NON-WATERTIGHT BULKHEADS		
Boundary connections to tank top ... ..	0,14	no scallops
Boundary connections elsewhere ... ..	0,10	when supporting pillars above
Stiffeners used as pillars ... ..	0,14	
Stiffeners elsewhere ... ..	0,10	
FORWARD AND AFT PEAK STRUCTURE		
Peak bulkheads ... ..	—	(as for Deep Tanks and Bunkers)
Bottom frames to shell and floors, and floor plates to shell ... ..	0,12	in fore peak
Side frames ... ..	0,21	in aft peak ( <i>see</i> Note 6)
	0,12	in fore peak
	0,21	in aft peak ( <i>see</i> Note 6)
	0,10	
Floors and cross ties to frames in fore peak ...	0,10	
Floors and cross ties to frames in aft peak ...	0,21	<i>see</i> Note 6
Beams at crown of fore peak to deck ...	0,12	<i>see</i> Note 6
Beams at crown of aft peak to deck ...	0,21	<i>see</i> Note 6
DECKS, BEAMS AND DECK LONGITUDINALS		
Strength deck to shell ... ..	—	full penetration weld
Other decks to shell and other boundaries ...	depends on design	generally 0,21 continuous
Cantilever beams to deck ... ..	depends on design	generally 0,21 or 0,14
Cantilever brackets to deck and shell ...	0,44	continuous
Cantilever bracket face bar ... ..	0,21	continuous
Cantilever beam and bracket stiffeners ...	0,14	
Hatch end strong beams to deck ... ..	0,14	
Transverse beams to deck ... ..	0,10	
Longitudinals to deck ... ..	0,10	<i>see</i> Note 1 and Note 6
Deck longitudinals of the flat bar or plate type to deck plating... ..	0,25	but need not exceed 5,5 mm hand, or 4,5 mm automatic. <i>See also</i> Note 1
Beam knees ... ..	Continuous weld	continuous. <i>See</i> Note 7
Lugs and brackets on half beams to hatch coamings and casings ... ..		6,5 cm <sup>2</sup> of welding for beams not exceeding 200 mm and 9,5 cm <sup>2</sup> of welding for beams exceeding 200 mm depth
DECK GIRDERS, TRANSVERSES AND WEBS		
Connections to plating ... ..	0,21	continuous in way of end brackets elsewhere generally continuous face bar area greater than 30 cm <sup>2</sup> face bar area not exceeding 30 cm <sup>2</sup>
End brackets ... ..	0,14	
	0,35	
	0,12	
Web to face bars ... ..	0,10	

TABLE D 32.1 (conclusion)

ITEM	WELD FACTOR	REMARKS
PILLARS		
Pillars built of rolled sections or plates ...	0,10	up to 0,35 in special cases—see also D 1410 see also D 1410 see also D 1817
End connections of widely spaced pillars ...	0,35	
Bulkhead stiffeners acting as pillars supporting pillars above ... ..	0,14	
HATCHWAYS		
Coaming to deck ... ..	0,35	generally
Coaming to deck at corners ... ..	0,44	may be increased in special cases
Coaming stiffeners ... ..	0,10	
Hatch beam bars and face plates to webs, and stiffeners of pontoon covers... ..	0,10	generally—may be increased in special cases
VENTILATORS		
Coaming connection to weather decks ...	0,35	
Elsewhere ... ..	0,21	
STEMS AND STERNFRAMES		
Stem breasthooks and stiffeners ... ..	0,21	
Sternframes (main load-bearing items) ...	0,44	
Sternframes elsewhere ... ..	0,21	
RUDDERS		
Fabricated mainpiece and mainpiece to rudder side plates and webs... ..	0,44	
Elsewhere ... ..	0,21	
Slot welding ... ..	0,44	
MASTS		
Main structure ... ..	0,44	full penetration generally required 0,21
Cargo gear fittings ... ..		
Minor fittings ... ..		



NOTES TABLE D 32.1

1. Thickness to be used in determining throat thickness is generally to be that of the thinner of the two parts being joined.

Where slab type longitudinals are fitted to the bottom shell, upper deck, or longitudinal oiltight bulkheads in the top or bottom 0,1D, within 0,4L amidships, the thickness used to determine the throat thickness is not to be less than half the thickness of the longitudinal.

Where the difference between the thicknesses of the parts to be joined is considerable, the size of fillet will be specially considered.

2. Throat thickness for double continuous fillets is to be the product of the plate thickness and the weld factor given in Table D 32.1.

In no case (except for slab longitudinals) is the throat thickness to be less than 0,21 × plate thickness nor is it to be less than 3,5 mm for hand and automatic welding or 3 mm for automatic deep penetration welding.

For hand welded fillet welds on internal bulkheads not exceeding 6 mm in thickness, a minimum throat thickness of 3 mm is acceptable.

Within the cargo tanks of oil tankers, or in areas of similar construction on other ships, fillets having a throat thickness of less than 0,35 of the plate thickness are to be restricted to longitudinal framing and to bulkhead stiffening.

Where automatic deep penetration welds are used the values derived as above may be reduced by 15 per cent.

3. Throat thickness for intermittent fillets is to be obtained by the formula:—

$$\text{Throat thickness} = \text{plate thickness} \times \text{weld factor} \times \frac{d}{s}$$

where *d* and *s* are defined in Fig. 32.1.

The length *s* should not be less than 75 mm and the ratio of *d* to *s* is to be such that the required throat thickness does not exceed 0,49 × plate thickness or 4,5 mm whichever be the greater.

In no case, however, is the throat thickness of intermittent fillet welds to be less than 0,28 × plate thickness or 3,5 mm, whichever be the greater.

4. Leg length of welds is not to be less than  $\sqrt{2}$  times the throat thickness derived as above.

5. Where the top and bottom strakes of the longitudinal bulkhead are increased in thickness above the requirements of D 5009, the welding to deck or bottom shell is not to be less than that based on the thickness required by D 5009 or a throat thickness 25 per cent of the actual plating thickness, whichever is the greater.

6. Fillet welds in after peak tanks and on after peak bulkhead stiffeners and all welding in deep tanks intended for chemicals and edible liquids are to be continuous. It is recommended that all fillet welds in all tanks be continuous.

Where the thickness of bottom or deck longitudinals exceeds the thickness of the shell or deck plating the welding is to be continuous.

7. Welding at the ends of bulkhead stiffeners, etc., (whether associated with brackets or lugs) is to give, when not otherwise specified in Tables D 32.1, D 32.2, D 32.3 and D 32.4, a weld area (length of weld × throat thickness) of 25 per cent of the cross-sectional area of the stiffener with a minimum of 6,5 cm<sup>2</sup>.

8. The welding of girders, webs, beams and frames to shell and deck in way of end brackets, or knees that require continuous welds, should also be continuous.

#### STAGGERED INTERMITTENT

To be doubled at ends. See D 3210

#### CHAIN INTERMITTENT

#### SCALLOPED FRAMES, LONGITUDINALS, STIFFENERS, etc., WITH DOUBLE FILLET WELDS

See also D 3211

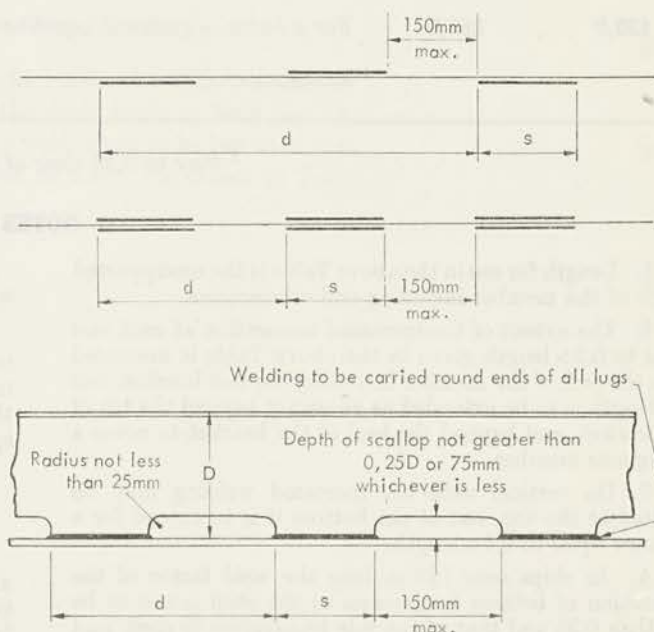


FIG. D 32.1 WELD TYPES

TABLE D 32.2

## CONNECTION OF PRIMARY SUPPORTING MEMBERS TO FACE MATERIAL, SHELL, DECK AND BULKHEAD

FACE AREA	POSITION	WELDED	
		TO FACE MATERIAL	TO SHELL, DECK OR BULKHEAD
		WELD FACTOR	WELD FACTOR
$\text{cm}^2$ Exceeding      Not exceeding <b>30,0</b>	For a distance each end equal to $0,2 \times \text{length}$ ... Remainder ... ..	0,15 0,10	0,30 0,15
<b>30,0</b> <b>65,0</b>	For a distance each end equal to $0,2 \times \text{length}$ ... Remainder ... ..	0,22 0,12	0,35 0,27
<b>65,0</b> <b>95,0</b>	For a distance each end equal to $0,2 \times \text{length}$ ... Remainder ... ..	0,35 0,35*	0,44 0,35
<b>95,0</b> <b>130,0</b>	For a distance each end equal to $0,2 \times \text{length}$ ... Remainder ... ..	0,35 0,35*	0,44 0,35
<b>130,0</b> <b>260,0</b>	For a distance each end equal to $0,2 \times \text{length}$ ... Remainder ... ..	0,44 0,35	0,44 0,35

\* May be 0,28 clear of oil cargo tanks

## NOTES

1. Length for use in the above Table is the unsupported length of the member including end connections.

2. The extent of the increased connection at each end equal to  $0,2 \times \text{length}$  given in the above Table is measured from the end of the member including the end bracket, but this length is to be extended as necessary beyond the toe of the bracket, and beyond the heel of the bracket to cover a contiguous member.

3. On vertical webs the increased welding may be omitted at the top, but at the bottom it is to extend for a distance equal to  $0,3 \times \text{length}$ .

4. In ships over 122 m long the weld factor of the connection of bottom transverses to the shell is not to be less than 0,35 and that of the side transverses to shell, and the vertical webs to longitudinal and transverse bulkheads is not to be less than 0,35 in the lower half.

5. Centreline deck and bottom girders are to be welded as given in the above Table.

6. The weld connection to shell, deck or bulkhead is to take account of the material lost in the notch where longitudinals or stiffeners pass through the member. Where the width of notch exceeds 15 per cent of the stiffener spacing, the weld factor given above is to be multiplied by:—

$$\frac{0,85 \times \text{stiffener spacing}}{\text{length of web plating between notches}}$$

7. Where direct calculation procedures have been adopted, the weld factors for the  $0,2 \times \text{length}$  at the ends of the members will be considered in relation to the calculated loads.

8. See Notes to Table D 32.1.



TABLE D 32.3

## WELDING OF STIFFENER END CONNECTIONS

1. The weld area  $A_w$ , connecting each arm of the bracket to the stiffener or plating, is to be not less than:—

$$A_w = 1,2 \sqrt{Z} \text{ cm}^2 \text{ generally, or}$$

$$A_w = 1,4 \sqrt{Z} \text{ cm}^2 \text{ in tanks.}$$

Weld area,  $A_w$ , is defined as the product of the throat thickness and the total length of weld.

$Z$  is the modulus, in  $\text{cm}^3$ , of the stiffener on which the scantlings of the bracket are based.

2. The throat thickness of the weld is to be not less than:—

0,28 of the bracket thickness, generally, or

0,35 of the bracket thickness in tanks,

and in no case is to be less than 3,5 mm.

3. Where a watertight bulkhead stiffener is directly connected at its ends to the deck, beam or tank top, i.e. brackets are not fitted, the weld is not to be less than that required for a weld factor of 0,44. See Notes to Table D 32.1.

TABLE D 32.4

## CONNECTIONS OF LONGITUDINALS, FRAMES AND STIFFENERS TO PRIMARY SUPPORTING MEMBERS

1. The weld area connecting longitudinals, frames and stiffeners to primary supporting members is not to be less than the greater of the values given by the following formulæ:—

$$\text{Bottom Transverses} \quad A = 0,88 \sqrt{\frac{I}{y}} \quad \text{or} \quad 0,0612 \frac{1}{S} \frac{I}{y} \text{ cm}^2$$

$$\text{Deck Transverses} \quad A = 0,44 \sqrt{\frac{I}{y}} \quad \text{or} \quad 0,0306 \frac{1}{S} \frac{I}{y} \text{ cm}^2$$

$$\begin{array}{l} \text{Side Transverses} \\ \text{and bulkhead webs} \\ \text{and girders} \end{array} \quad A = 0,88 \sqrt{\frac{I}{y}} \quad \text{or} \quad 0,109 \frac{1}{S} \frac{I}{y} \text{ cm}^2$$

In no case is the area to be less than 13 cm<sup>2</sup>

where A = area of weld, in cm<sup>2</sup>, as defined in 2 below,

$\frac{I}{y}$  = section modulus of longitudinal, frame or stiffener, in cm<sup>3</sup>,

S = span of longitudinal, frame or stiffener, in metres.

2. Area of weld is the product of the throat thickness and total length of weld and includes both weld of web connection and weld of connection to stiffening bar. The throat thickness is not to be less than 0,35 of the plate thickness, or 3 mm, whichever be the greater.

3. Outside the tank space the area of weld may be 80 per cent of the value required by the formula and associated Notes. The throat thickness of weld is not to be less than 0,30 of the plate thickness, or 3 mm, whichever be the greater.



**Additional Attachment**

**3212** Welded connections may require to be increased to meet particular local stresses, or where otherwise necessary.

**Workmanship**

**3213** Welding operators are to be proficient in the type of work on which they are engaged. A sufficient number of skilled supervisors is to be provided to ensure effective control at all stages of assembly and welding operations. The welding plant and appliances are to be suitable for the purpose intended and are to be maintained in an efficient condition.

**3214** Procedures for the welding of all joints are to be established for the types of electrode, edge preparation and welding position proposed. For this purpose, the Surveyors may require sample tests to be prepared under similar conditions to those which will obtain during construction.

The diameter of electrode, current, voltage, rate of deposit and number of runs are to conform, so far as practicable, to those established in accordance with the preceding sub-paragraph. Provision is to be made for checking the current in the vicinity of the arc.

**3215** The preparation of plate edges is to be accurate and uniform. All joints are to be properly aligned and closed or adjusted before welding. Excessive force is not to be used in fairing and closing the work. Means are to be provided for holding the work in proper alignment without rigid restraint during welding operations.

Where excessive gaps exist between surfaces or edges to be joined, the corrective measures adopted are to be to the satisfaction of the Surveyors.

**3216** Tack welding should be kept to a minimum and where used should be equal in quality to the finished welds. All defective tack welds should be cut out before completing the finished welds.

Care should be taken when removing tack welds and temporary fittings used for assembly to ensure that the material of the hull is not damaged.

**3217** The surfaces of all parts to be welded are to be clean, dry, and free from rust, scale and grease. The surfaces and boundaries of each run of deposit are to be thoroughly cleaned and freed from slag before the next run is applied.

Before a manual sealing run is applied to the back of a weld the original root run is to be cut back to sound metal.

Welding is to proceed systematically, each welded joint being completed in proper sequence without undue interruption.

Adequate protection is to be provided where welding is required to be carried out in exposed positions in wet, windy or cold weather. In cold weather, precautions should be taken to screen and pre-warm the work where necessary to prevent too rapid cooling of the weld; special care is necessary when welding thick material.

**3218** All finished welds are to be sound, uniform and substantially free from slag inclusions, porosity, undercutting or other defects. Care is to be taken to ensure thorough penetration and fusion.

**Welding of Higher Tensile Steel**

**3219** Where higher tensile steel is employed, the requirements as laid down in this Section are to be carried out in so far as they are applicable, with the following amendments:—

- (a) When the carbon equivalent, calculated from the ladle analysis and using the formula given below, is in excess of 0.45%, approved low hydrogen higher tensile electrodes and preheating are to be used. When the carbon equivalent is above 0.41% but is not more than 0.45%, approved low hydrogen higher tensile electrodes are to be used but preheating will not generally be required except under conditions of high restraint or low ambient temperature. When the carbon equivalent is not more than 0.41%, any type of approved higher tensile electrodes may be used and preheating will not generally be required except as above.

Carbon equivalent =

$$C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15}$$

This formula is applicable only to steels which are basically of the carbon-manganese type containing minor quantities of grain refining elements, for example, niobium, vanadium or aluminium. The proposed use of low alloy steels will be subject to special consideration.

- (b) Welding procedures and techniques are to be demonstrated as satisfactory by shipyard tests, see 3214.
- (c) Fillet welds are to be continuous.
- (d) Butt welds are to have a smooth profile without excessive build up.
- (e) Random non-destructive testing is to be carried out especially at highly stressed items. Magnetic crack detecting or equivalent tests are to be used at the ends of fillet welds, tee joints and other



joints where welds join or cross in main structural members. Butt welds and highly stressed items elsewhere are to be X-rayed or given other equivalent tests.

**3220** Where the structure incorporates both mild steel and higher tensile steel, details of the welding arrangements and procedures at the interchange joints are to be submitted for approval in all cases where the chemical analysis of the higher tensile steel requires that it be preheated or heat treated after welding.

#### Welding of Aluminium Alloys

**3221** Where welding of aluminium alloys is employed, the requirements as laid down in this Section are to be carried out so far as they are applicable, with the following additions:—

The edges of the material to be welded are to be clean and freed from grease by chemical or solvent cleaning. The joint edges should be scratch brushed—preferably immediately before welding—in order to remove oxide or adhering films of dirt, filings, etc.

Parts to be welded should be set up in such a way that contraction stresses are kept to a minimum.

For welding processes and filler wire, *see* P 14.

### Section 33

#### STRUCTURAL DETAILS

**3301** Special attention is to be paid to structural continuity. Abrupt changes of shape or section and all sharp corners are to be avoided. The endings of bulwarks, bilge keels or similar attachments to the hull are to be gradually tapered.

**3302** For details of openings in strength deck, *see* D 407 to D 412.

For details of openings in shell plating, *see* D 514.

**3303** Bulwarks, fairlead stools, mouldings and other fittings are not to be welded to the top edge of the sheer-strake within 0.5L amidships. The top edge of the sheer-strake is to be free of all notches and is to be smooth.

**3304** Manholes, lightening holes, slots, scallops and notches should be avoided in way of concentrated loads, including high shear loads. In particular, manholes and similar openings should not be cut in vertical or horizontal plate webs in narrow cofferdams within one-third of the length of the webs from each end, nor in floors or double bottom girders close to the toes of bilge or bulkhead brackets

unless the stresses in the remaining web plating are calculated and found to be satisfactory. (*See* D 933, D 946 and D 948.)

**3305** Where practicable, pillars and bulkheads should be placed in the same vertical line. Beam slots in girders, etc., adjacent to concentrated loads should be collared.

**3306** The toes of brackets, etc., should not land on unstiffened panels of plating unless the bracket is well hollowed out and extends close to an adjacent stiffener.

Where large brackets are fitted, sharp angles at their toes should be avoided by making the free edge of the bracket concave or by other means. Special care should be taken to avoid notch effects at the toes of brackets, etc.

**3307** The standard of welding and general workmanship of bilge keels, rubbing bars and other similar items attached to highly stressed parts of the ship should be as high as that for the main structural items themselves. The welding of minor items to main structural members is to be avoided where possible.

The ends of bilge keels are to be well sniped and arranged to land in way of an internal stiffener such as a frame, floor or transverse. Such items should be continuous over shell butts, the butt being first made flush in way. Ratholes and scallops should be avoided. The butts of bilge keels should be completed before the bilge keels are welded to the shell. *See* D 517.

**3308** The use of backing bars in highly stressed welds is to be avoided where possible. When backing bars are unavoidable, (e.g. in certain rudder designs) special care is to be taken to ensure accurate fit-up. Welding, especially in way of butts of the backing bar, is to be of the highest quality. *See also* D 2221 for welding of rudders.

**3309** When stiffening members are attached by continuous fillet welds and cross completely finished butt or seam welds, these welds are to be made flush in way of the faying surface. Similarly, for butt welds in webs of stiffening members the butt weld should be completed and generally made flush with the stiffening member before the fillet weld is made.

Where these conditions cannot be complied with, a scallop is to be arranged in the web of the stiffening member. Scallops are to be of such a size, and in such a position, that a satisfactory weld can be made.

**3310** Where thick plates are butt welded to thin plates, the edge of the thick plate may require to be tapered. The taper is generally not to exceed 1 in 3.

Where butt welds form a Tee junction, the "leg" of the Tee should, where practicable, be completed (including the back run, if any) before the "table" is welded.



If all three plates are in position when the "leg" of the Tee is welded, steps should be taken to protect the cross plate either by wedging up the two plates adjoining the "leg" of the Tee clear of the cross plate, or else by using a shield of some sort. The "leg" welding should be completed full at the junction and then chipped flush to remove crater cracks, etc.

Where the "leg" is welded before the cross plate is fitted, it is good practice to fit a temporary "run off" plate to allow the Tee "leg" welding to continue past the parent plate edge. When this is done, the run off plate should be clamped in position and not welded unless a trimming edge has been left on the parent plates, in which case the run off plate may be welded to one only of the parent plates.

Where butt welds have been chipped or ground flush to permit fillet welds of abutting members to cross them, care is to be taken to ensure that the ends of the flush portion run out smoothly without notches or sudden change of section.

**3311** In higher tensile steel stiffening members, particular attention is to be paid to air holes and drain holes. These should be cut clear of the fillet weld wherever this is practicable. Where it is necessary to arrange such holes flush with the attached plating, the holes are to be of elliptical shape.

## Section 34

### EQUIPMENT

#### General

**3401** The regulations governing the assignment of the figure 1 for equipment are contained in B 201 and B 202.

**3402** To entitle a ship to the figure 1, the equipment is to be in accordance with the following requirements and Table D 34.1. For ships engaged on a special or restricted service, an equipment differing from the Table requirements may be approved by the Committee if considered suitable for the particular service on which the ship is to be engaged. (See D 3541 and D 89.)

Special consideration will, however, be given to requests from Owners to store the third (spare) anchor ashore, for ships without any restrictive notation, where special circumstances are such that safety is not thereby significantly impaired.

#### Equipment Number

**3403** The equipment of anchors and chain cables given in Table D 34.1 is based on an "Equipment Number" which is to be calculated as follows:—

$$\text{Equipment Number} = \Delta^{\frac{1}{3}} + 2 Bh + \frac{A}{10}$$

where  $\Delta$  = moulded displacement, in tonnes to the summer load waterline,

$B$  = greatest moulded breadth, in metres,

$h$  = freeboard amidships, in metres, from the summer load waterline to the upper deck plus the sum of the heights at the centreline, in metres, of each tier of houses having a breadth greater than  $B/4$ . (See also 3404, 3405 and 3406)

$A$  = area, in  $m^2$ , in profile view of the hull, within the Rule length of the vessel, and of superstructures and houses above the summer load waterline, which are within the Rule length of the vessel, and also having a width greater than  $B/4$ . (See also 3405 and 3406.)

**3404** When calculating  $h$ , sheer and trim are to be ignored. Where there is a local discontinuity in the upper deck,  $h$  is to be measured from a notional deckline.

**3405** If a house having a breadth greater than  $B/4$  is above a house with a breadth of  $B/4$  or less, then the wide house is to be included, but the narrow house ignored.

**3406** Screens and bulwarks more than 1.5 m in height are to be regarded as parts of houses when determining  $h$  and  $A$ . Where a screen or bulwark is of varying height, the portion to be included is to be that length the height of which exceeds 1.5 m.

#### Anchor Weights

**3407** The weight of each bower anchor, given in Table D 34.1, is for anchors of equal weight. The weight of individual anchors may vary by  $\pm 7$  per cent of the Table weight provided that the total weight of anchors is not less than would have been required for anchors of equal weight.

**3408** The weight of the head, including pins and fittings, of an ordinary stockless anchor is not to be less than 60 per cent of the total weight of the anchor.

**3409** When stocked bower or stream anchors are to be used, the weight "ex stock" is not to be less than 80 per cent of the Table weight for ordinary stockless bower anchors. The weight of the stock is to be 25 per cent of the total weight of the anchor, including the shackle, etc., but excluding the stock.

**3410** When anchors of a design approved for the designation "High Holding Power" are used as bower anchors, the weight of each such anchor may be 75 per cent of the Table weight for ordinary stockless bower anchors.



TABLE D 34.1 EQUIPMENT

EQUIPMENT NUMBER (See D 3403)		EQUIP- MENT LETTER	STOCKLESS BOWER ANCHORS		STUD LINK CHAIN CABLES FOR BOWER ANCHORS			
Exceeding	Not Exceeding		Number	Weight per Anchor (kg)	Total Length (m)	Diameter (mm)		
						Mild Steel (Grade 1 or U 1)	Special Quality Steel (Grade U 2)	Extra Special Quality Steel (Grade U 3)
280	320	J	3	900	357,5	30	26	—
320	360	K	3	1020	357,5	32	28	—
360	400	L	3	1140	385	34	30	—
400	450	M	3	1290	385	36	32	—
450	500	N	3	1440	412,5	38	34	—
500	550	O	3	1590	412,5	40	34	—
550	600	P	3	1740	440	42	36	—
600	660	Q	3	1920	440	44	38	—
660	720	R	3	2100	440	46	40	—
720	780	S	3	2280	467,5	48	42	—
780	840	T	3	2460	467,5	50	44	—
840	910	U	3	2640	467,5	52	46	40
910	980	V	3	2850	495	54	48	42
980	1060	W	3	3060	495	56	50	44
1060	1140	X	3	3300	495	58	50	46
1140	1220	Y	3	3540	522,5	60	52	46
1220	1300	Z	3	3780	522,5	62	54	48
1300	1390	A†	3	4050	522,5	64	56	50
1390	1480	B†	3	4320	550	66	58	50
1480	1570	C†	3	4590	550	68	60	52
1570	1670	D†	3	4890	550	70	62	54
1670	1790	E†	3	5250	577,5	73	64	56
1790	1930	F†	3	5610	577,5	76	66	58
1930	2080	G†	3	6000	577,5	78	68	60
2080	2230	H†	3	6450	605	81	70	62
2230	2380	I†	3	6900	605	84	73	64
2380	2530	J†	3	7350	605	87	76	66
2530	2700	K†	3	7800	632,5	90	78	68
2700	2870	L†	3	8300	632,5	92	81	70
2870	3040	M†	3	8700	632,5	95	84	73
3040	3210	N†	3	9300	660	97	84	76
3210	3400	O†	3	9900	660	100	87	78
3400	3600	P†	3	10 500	660	102	90	78
3600	3800	Q†	3	11 100	687,5	105	92	81
3800	4000	R†	3	11 700	687,5	107	95	84
4000	4200	S†	3	12 300	687,5	111	97	87
4200	4400	T†	3	12 900	715	114	100	87
4400	4600	U†	3	13 500	715	117	102	90
4600	4800	V†	3	14 100	715	120	105	92
4800	5000	W†	3	14 700	742,5	122	107	95
5000	5200	X†	3	15 400	742,5	124	111	97
5200	5500	Y†	3	16 100	742,5	127	111	97
5500	5800	Z†	3	16 900	742,5	130	114	100
5800	6100	A*	3	17 800	742,5	132	117	102
6100	6500	B*	3	18 800	742,5	—	120	107
6500	6900	C*	3	20 000	770	—	124	111
6900	7400	D*	3	21 500	770	—	127	114
7400	7900	E*	3	23 000	770	—	132	117
7900	8400	F*	3	24 500	770	—	137	122
8400	8900	G*	3	26 000	770	—	142	127
8900	9400	H*	3	27 500	770	—	147	132
9400	10 000	I*	3	29 000	770	—	152	132
10 000	10 700	J*	3	31 000	770	—	157	137
10 700	11 500	K*	3	33 000	770	—	157	142
11 500	12 400	L*	3	35 500	770	—	162	147
12 400	13 400	M*	3	38 500	770	—	—	152
13 400	14 600	N*	3	42 000	770	—	—	157
14 600	16 000	O*	3	46 000	770	—	—	162



**Anchor Design**

**3411** Anchors are to be of approved design. The design of all anchor heads is to be such as to minimize stress concentrations and, in particular, the radii on all parts of cast anchor heads are to be as large as possible, especially where there is considerable change of section.

**3412** For approval as a "High Holding Power" anchor, see P 706.

**Chain Cables**

**3413** Chain cables may be of wrought iron, mild steel, special quality steel or extra special quality steel in accordance with the requirements of P 8 and are to be graded in accordance with Table D 34.2 (see also P 801).

**TABLE D 34.2**

GRADE	MATERIAL	TENSILE STRENGTH	
		N/mm <sup>2</sup>	(kgf/mm <sup>2</sup> )
1(a)	Wrought iron	300-400	(31-41)
1(b)	Mild steel	300-400	(31-41)
U 1(a)	Mild steel	300-400	(31-41)
U 1(b)	Mild steel	400-490	(41-50)
U 2(a)	Special Quality steel	490-640	(50-65)
U 2(b)	Special Quality cast steel	490 min.	(50 min.)
U 3	Extra Special Quality steel	690 min.	(70 min.)

**3414** Grades 1(a), 1(b) or U 1(a) materials are not to be used in association with high holding power anchors.

Grade U 3 material is only to be used for chain 40 mm or more in diameter.

**3415** The form and proportion of links and shackles are to be in accordance with International Standard ISO/1704-1973 (see Figs. D 34.1, D 34.2, D 34.3 and Section P 8).

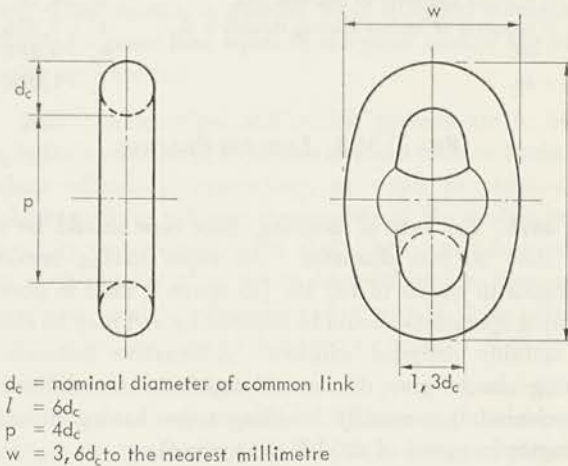
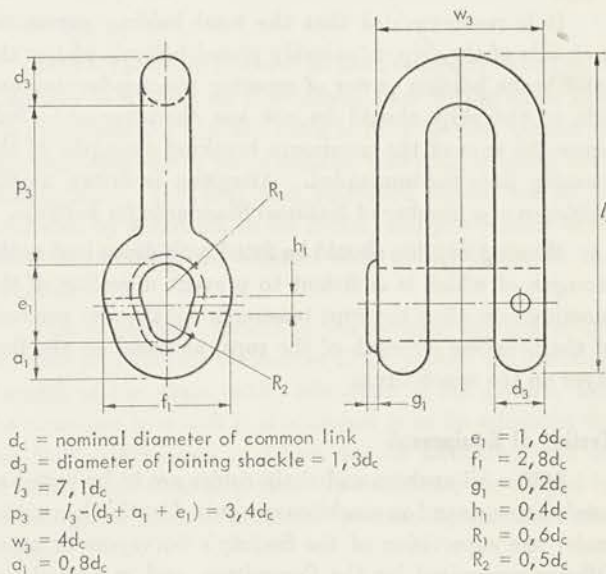
**Towlines and Mooring Lines**

**3416** Towlines and mooring lines are not a classification requirement for ships of 90 m and over, in length. It is recommended, however, that the sum of the strengths of all the mooring lines supplied to such ships should be not less than the Rule breaking load of one anchor cable as required by Table D 34.1 and Table P 8.3, based on Grade U 2 chain for ships with equipment numbers up to 12 400

and on Grade U 3 chain for ships with higher equipment numbers. On ships regularly using exposed berths, twice the above total strength of mooring ropes can be desirable.

Where a separate towline is supplied, it is recommended that its strength be not less than 40 per cent of the strength of the anchor cable.

**3417** It is recommended that not less than four mooring ropes be carried on ships exceeding 90 m in length, and not less than six ropes on ships exceeding 180 m in length. The length of mooring ropes should be not less than 200 m, or the length of the ship, whichever is the lesser.

**FIG. D 34.1 COMMON LINK****FIG. D 34.2 DEE SHACKLE**



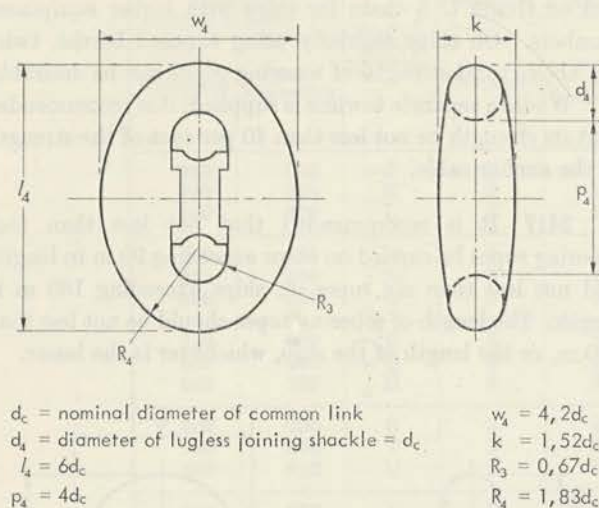


FIG. D 34.3 LUGLESS SHACKLE

**3418** For ease of handling, fibre rope should be not less than 20 mm diameter. All ropes having breaking strengths in excess of 735 kN (75 tonne-f) used in normal mooring operations should be handled by and may be stored on suitably designed winches. Alternative methods of storing should give due consideration to the difficulties experienced in manually handling ropes having breaking strengths in excess of 490 kN (50 tonne-f).

#### Means of Securing Mooring Lines

**3419** Means should be provided to enable mooring lines to be adequately secured on board ship.

It is recommended that the total holding power, on each side of the ship, of suitably placed bollards and/or the total brake holding power of mooring winches serving one side of the ship, should be not less than one-and-a-half times the sum of the maximum breaking strengths of the mooring lines recommended. Attention is drawn to the existence of a number of National Standards for bollards.

Mooring winches should be fitted with drum brakes the strength of which is sufficient to prevent unreeling of the mooring line when the rope tension is equal to 80 per cent of the breaking strength of the rope, as fitted on the first layer on the winch drum.

#### Testing of Equipment

**3420** All anchors and chain cables are to be tested at establishments and on machines recognized by the Committee under the supervision of the Society's Surveyors or other Officers recognized by the Committee, and in accordance with P 7 and P 8.

**3421** Test certificates showing particulars of weights of anchors, or size and weight of cable and of the test loads applied are to be furnished. These certificates are to be examined by the Surveyors when the anchors and cables are placed on board the ship.

#### Arrangements for Working and Stowing Anchors and Cables

**3422** A windlass of sufficient power and suitable for the size of chain cable is to be fitted and efficiently bedded and secured to the deck. The thickness of the deck in way of the windlass is to be increased and adequate stiffening is to be provided, to the Surveyor's satisfaction.

**3423** For the information of Builders and Owners, the following performance criteria will normally be used to determine if a windlass has sufficient power and is suitable for its purpose:—

- It should be capable of exerting, for a period of 30 minutes, a continuous duty pull of  $41,68 d_c^2 N$  ( $4,25 d_c^2 \text{ kgf}$ ) where  $d_c$  is the chain diameter in mm.
- It should be capable of exerting a pull for at least 2 minutes of  $62,76 d_c^2 N$  ( $6,4 d_c^2 \text{ kgf}$ ) or, if it be greater, a pull sufficient to raise a standard stockless anchor associated with Grade U 2 chain from a depth equal to 25 per cent of the total length of chain required to be carried on board by Table D 34.1, column 6, i.e. approximately 50 per cent of the length of the cable carried on one side of the ship.
- It should be capable, on trial on board ship, of raising an anchor from a depth of 82,5 m to a depth of 27,5 m at a mean speed of not less than 9 m/min. Where the depth of water in trial areas is inadequate, consideration will be given to the acceptance of equivalent simulated conditions.
- It should be able to withstand, with the brakes fully applied, a proof load of  $6,18 d_c^2 (44 - 0,08 d_c) N$  ( $0,63 d_c^2 (44 - 0,08 d_c) \text{ kgf}$ ) applied to the cable.
- It should be designed so as not to suffer collapse such as could release the cable if a load equal to the breaking load of the cable is applied to the cable.

Attention should be paid to stress concentrations in keyways and other stress raisers and also to the effect of snatch loading or sudden stopping of the prime mover or anchor chain.



It should be noted that the above criteria do not require both anchors to be raised or lowered simultaneously on windlasses fitted with two cable lifters, but consideration must be given to minimizing the probability of declutching a cable lifter from the motor with the gipsy brake in the off position.

**3424** When consideration of the criteria in 3423 is being undertaken by the Society, the following assumptions will be made:—

- (a) cable weights will be assumed to be as given in Fig. D 34.4.
- (b) hawse pipe efficiency will be assumed to be 70 per cent.
- (c) anchor weights will be assumed to be as given in Table D 34.1, i.e. without the  $\pm 7$  per cent weight tolerances.

**3425** The design of the windlass is to be such that:—

- (a) a weathertight connection can be made between the windlass bedplate, or its equivalent, and the upper end of the chain pipe, and

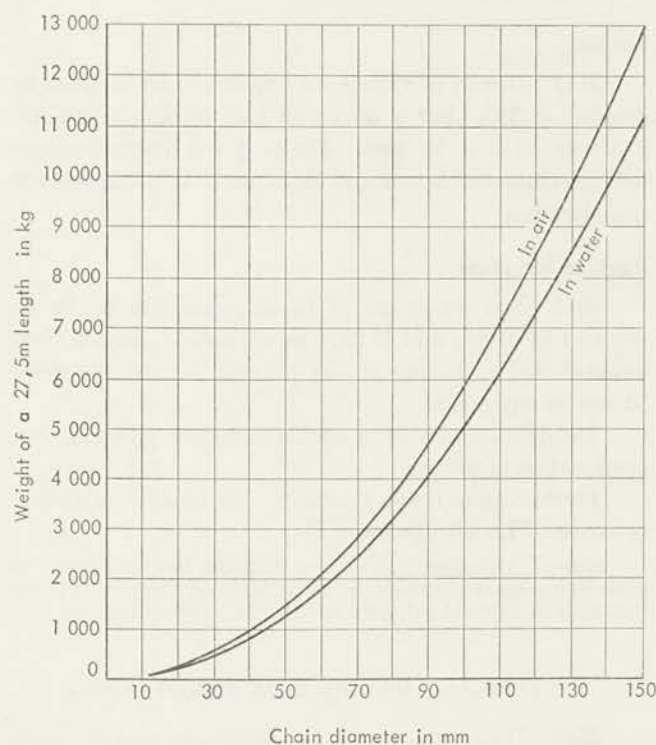


FIG. D 34.4 TYPICAL CHAIN CABLE WEIGHTS

- (b) access to the chain pipe is adequate to permit the fitting of a cover or seal, of sufficient strength and proper design, over the chain pipe while the ship is at sea.

The above requirements or equivalent arrangements are intended to minimize the probability of the chain locker or forecastle being flooded in bad weather.

**3426** An easy lead of the cables from the windlass to the anchors and chain locker is to be arranged. Where cables pass over or through stoppers, these stoppers are to be manufactured from ductile material and be designed to minimize the probability of damage to, or snagging of, the cable. They should, in general, be of sufficient strength to withstand a proof load equal to the proof load of the cable passing over them.

**3427** Hawse pipes and anchor pockets are to be of ample thickness and of a suitable size and form to house the anchors efficiently, preventing, as much as practicable, slackening of the cable or movements of the anchor being caused by wave action. The shell plating and framing in way of the hawse pipes are to be reinforced as necessary. Reinforcing is also to be arranged in way of those parts of bulbous bows liable to be damaged by anchors or cables.

Substantial chafing lips are to be provided at shell and deck. These are to have sufficiently large radiused faces to minimize the probability of cable links being subjected to high bending stresses.

Alternatively, roller fairleads of suitable design may be fitted. Where unpocketed rollers are used it is recommended that the roller diameter be not less than 11 times the chain diameter.

**3428** The chain locker is to be of a capacity and depth adequate to provide an easy direct lead for the cable into the chain pipes, when the cable is fully stowed. Chain or spurling pipes are to be of suitable size and provided with chafing lips. The port and starboard cables are to be separated by a division in the locker, and provision is to be made for securing the inboard ends of the cables to the structure.

This attachment should have a working strength of not less than 63.7 kN (6.5 tonne-f) or 10 per cent of the breaking strength of the chain cable, whichever is the greater, and the structure to which it is attached is to be adequate for this load. Attention is drawn to the advantages to be obtained from arranging that the cable may be slipped in an emergency from an accessible position outside the chain locker.



**FERRIES****Section 35****General**

**3501** The scantlings and arrangements of ferries are to be in accordance with the requirements of the preceding Sections of this Chapter, and as detailed below as relevant.

**Omission of Bulkheads**

**3502** Where there are no transverse bulkheads in way of vehicle decks, then web frames and deck transverses should be fitted. The arrangements will be specially considered for transverse strength.

**PERMANENT VEHICLE DECKS****Loading**

**3503** Decks for the carriage of vehicles (cars, trucks, etc.) are to be designed on the basis of the maximum wheel loading to which they may be subjected in service.

Builders are to supply details of tyre pressure, wheel size, wheel loads and tyre print dimensions.

**Plating**

**3504** Vehicle deck plating is to be in accordance with the requirements of D 421 for plating loaded by wheeled vehicles.

**Underdeck Structure**

**3505** Scantlings of beams and longitudinals are to be in accordance with D 811 for wheeled vehicles.

Girders and transverses are to be designed for a stress not exceeding  $123,6 \text{ N/mm}^2$  ( $12,6 \text{ kgf/mm}^2$ ), in association with the maximum loads to which they will be subjected from wheels, etc.

**Vehicle/Cargo Decks**

**3506** When vehicle decks are also to be used for the carriage of cargo, the scantlings derived from 3504 and 3505 are not to be less than would be required by the relevant Sections of the Rules for cargo ships.

**Train Decks**

**3507** Decks for the transport of railway carriages on fixed rails will be specially considered.

**Securing Arrangements**

**3508** Details of the connection to the hull of vehicle securing arrangements are to be submitted for approval.

D 3501 - D 3513

**MOVABLE DECKS****Classification**

**3509** Movable decks are not normally a classification item, although consideration must be given to associated supporting structure.

When movable decks are fitted, it is recommended that they be based on the following criteria.

At Owner's or Builder's request, however, movable decks will be included as a classification item and the class notation "movable decks" will be entered in the Register Book. In such cases, all movable decks on board the ship are to comply with the requirements of 3510 to 3512.

**Arrangements and Design**

**3510** Movable decks are generally to be built as pontoons. Means are to be provided to secure decks in the lowered position.

Where supporting chains and fittings are required, they are to have a factor of safety of 2 on the proof load.

Proposals for racks, etc., for the stowing of pontoons on deck are to be submitted for consideration.

**Loading**

**3511** Details of vehicle loading are to be supplied as detailed in 3503, but a minimum axle loading of  $5,9 \text{ kN}$  ( $0,6 \text{ tonne-f}$ ) is to be used. The proposed design loadings for decks intended for general cargo are to be submitted for consideration.

**Pontoon Structure**

**3512** The scantlings of beams, etc., are to be as required by D 811 and D 2516 as applicable. In addition, however, the deflection of the pontoon is not to exceed  $50 \text{ mm}$  at any point.

The decking may be of steel, aluminium, plywood, or a combination of materials.

Plywood alone is not, generally, to be used for axle loads in excess of  $7,8 \text{ kN}$  ( $0,8 \text{ tonne-f}$ ).

NOTE. Attention is drawn to National fire regulations in some States which may ban the use of plywood and certain other materials in "special category spaces" on passenger ships.

**VEHICLE LOADING SIDE SHELL DOORS**

**3513** Doors are to be generally designed to open outboard, and have watertightness and structural integrity commensurate with the surrounding shell plating.

Stiffeners are not to be less than would be required by 3518.



**3514** Door openings in the side shell are to have well rounded corners, and adequate compensation is to be arranged (see D 514).

**3515** The lower edge of door openings is not to be below a line drawn parallel to the freeboard deck at side which has, as its lowest point, the upper edge of the uppermost load line, unless otherwise permitted by the National Authority concerned.

### BOW AND STERN DOORS

#### Definitions

**3516**

$S$  = span of stiffeners, in metres,

$s$  = spacing of stiffeners, in mm,

$h$  = head, in metres, from mid-span of stiffener to top of door, but is not to be taken less than 2 m,

$a$  = vertical distance, in metres, from the bow visor pivot to the centroid of the vertical projected area of bow visor,

$b$  = horizontal distance, in metres, from the bow visor pivot to the centroid of the horizontal projected area of the bow visor,

$c$  = horizontal distance, in metres, from bow visor pivot to centre of gravity of bow visor,

$d$  = vertical distance, in metres, from bow visor pivot to lowest closing device or cleat,

$W$  = weight of bow visor, in tonnes,

$A_v$  = the area, in  $m^2$ , of the vertical projection of the bow visor (see Fig. D 35.1),

$A_h$  = the area, in  $m^2$ , of the horizontal projection of the bow visor (see Fig. D 35.1),

$V$  = the volume, in  $m^3$ , of the bow visor,

$R_x$  = total horizontal force, in kN (tonne-f),

$R_z$  = total vertical force, in kN (tonne-f),

$\tau$  = shear stress, in  $N/mm^2$  (kgf/cm $^2$ ),

$\sigma$  = bending stress, in  $N/mm^2$  (kgf/cm $^2$ ),

$\sigma_c$  = combined stress, in  $N/mm^2$  (kgf/cm $^2$ ),

$$= \sqrt{\sigma^2 + 3\tau^2}$$

#### Scantlings

**3517** In general, the strength of bow and stern doors is to be equivalent to the surrounding structure.

Plating is not to be less than the minimum shell plating end thickness.

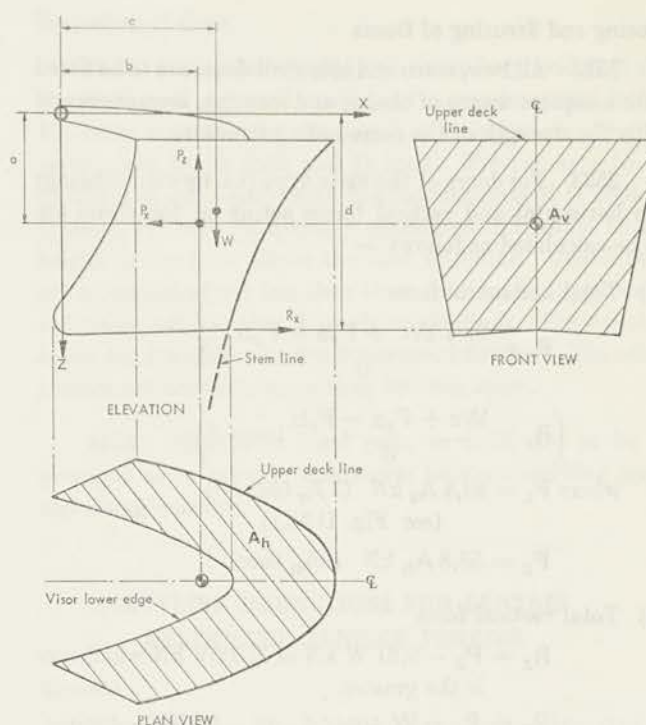


FIG. D 35.1 Bow Visor

**3518** The scantlings of stiffeners of stern doors, where not used for vehicle ramps, are not to be less than:—

$$\frac{I}{y} = \frac{S^2 s h}{98.4} \text{ cm}^3$$

Stiffeners are to be adequately supported by an efficient arrangement of webs and stringers.

**3519** Bow doors of the visor or hinged opening type are to be adequately stiffened, and means provided to prevent lateral or vertical movement of the doors when closed.

In visor type doors care is to be taken to ensure that adequate strength is provided in the connections of the lifting arms to the door structure.

#### Additional Inner Bow Door

**3520** Where bow doors are fitted, an inner door will also normally be required. The vehicle ramp may be used for this purpose.

#### Vehicle Ramps

**3521** Where doors also serve as vehicle ramps, the scantlings are not to be less than would be required by 3504 and 3505.



**Closing and Securing of Doors**

**3522** All bow, stern and side shell doors are to be fitted with adequate means of closing and securing, commensurate with the strength of the surrounding structure.

**3523** For doors of the visor type (i.e. upward hinging) the horizontal and vertical forces acting on the cleats are to be calculated as follows:—

(a) Total horizontal force

$$R_x = \frac{9,81 Wc + P_x a - P_z b}{d} \text{ kN}$$

$$\left( R_x = \frac{Wc + P_x a - P_z b}{d} \text{ tonne-f} \right)$$

where  $P_x = 29,4 A_v \text{ kN}$  ( $3 A_v \text{ tonne-f}$ )  
(see Fig. D 35.1)

$$P_z = 58,8 A_h \text{ kN} \quad (6 A_h \text{ tonne-f})$$

(b) Total vertical force

$$R_z = P_z - 9,81 W \text{ kN or } 10,05V \text{ kN whichever is the greater.}$$

$$(R_z = P_z - W \text{ tonne-f or } 1,025V \text{ tonne-f, whichever is the greater.})$$

The cleats and surrounding structure are to be designed to withstand these forces, using the following permissible stresses:—

$$\text{Shear stress } \tau = 83,4 \text{ N/mm}^2 \text{ (850 kgf/cm}^2\text{),}$$

$$\text{Bending stress } \sigma = 122,6 \text{ N/mm}^2 \text{ (1250 kgf/cm}^2\text{),}$$

$$\text{Combined stress } \sigma_c = 147,1 \text{ N/mm}^2 \text{ (1500 kgf/cm}^2\text{).}$$

Where more than one cleat is fitted on each side, the total vertical and horizontal forces are, for the purpose of calculation, to be distributed equally between the cleats. However,  $d$  may still be measured to the lowest closing device or cleat when calculating  $R_x$ .

**3524** Bow and outer doors are to be so fitted as to permit tightness consistent with operational conditions and to give maximum protection to inner doors.

Inner doors are to be gasketed and weathertight.

**3525** Stern doors are also to be gasketed and weathertight.

**Air Pipes**

**3526** Air pipes are to comply with the requirements of Chapter E and are to be of the height required by D 2911.

Air pipes are generally to be led to an exposed deck and fitted as required by D 2910 to D 2914 inclusive.

Alternative arrangements will be considered.

**Ventilators**

**3527** Ventilator coamings and closing appliances are to be as required by D 29. Where the freeboard length of the vessel is 100 m or less, permanently attached weathertight steel closing appliances are to be provided.

If any such ventilators are led overboard in an enclosed 'tween deck space, the closing arrangements are to be submitted for approval. If such ventilators are led overboard more than 4,5 m above the main vehicle deck, closing appliances need not be fitted, but a satisfactory baffle arrangement should be provided, as in the case of air intakes or exhaust openings for machinery spaces which may be arranged in the sides of the ship.

**Hatches**

**3528** Coamings of hatchways on weather decks, their closing and securing arrangements, are to be as required by D 26. Covers on small hatches are to be weathertight and preferably hinged. The spacing of securing devices is not to exceed 600 mm. Where toggles are fitted, their diameter is not to be less than 16 mm.

The height of hatch coamings may be reduced or these coamings omitted entirely, provided that the sealing arrangements are adequate and the safety of the ship is not thereby impaired in any sea condition. In such cases, the spacing of securing devices may require to be reduced. Each proposal for the reduction of hatch coaming height is to be specially considered in relation to hatch size and the height above the load waterline.

**Companionways, Doors and Windows**

**3529** Companionways and doors therein are to be as required by D 2646 and D 2647.

In ferries which carry passengers, all openings in the main vehicle deck, being in an enclosed 'tween deck space closed by bow and stern doors, and leading to spaces below, are generally to be protected by steel doors or hatch covers which are substantially weathertight. These openings are generally to have sills or coamings not less than 230 mm above the main vehicle deck, with the exception of those leading to machinery spaces which are to have sills or coamings not less than 380 mm.

Exceptionally, where such openings are to be kept closed at sea, sills or coamings may be reduced in height, provided that the sealing arrangements are adequate. In such cases, the doors or hatch covers are to be secured weathertight by gaskets and a sufficient number of clamping devices.



Such items as portable plates in the main vehicle deck arranged for the withdrawal of machinery parts, etc., may be arranged flush with the deck, provided that they are gasketed and weathertight by closely spaced bolts.

Closing appliances on the main vehicle deck are to comply with the requirements of Chapter F where appropriate.

**3530** All windows are to be in accordance with approved National Standards. Where they are fitted in a side-to-side erection over a superstructure giving direct access into that superstructure, which in turn has direct access down to an enclosed 'tween deck space, they are to be provided with efficient steel storm covers.

If the side-to-side erection is also the wheelhouse, openings within, leading below deck, should be individually protected.

In the first tier superstructure on the weather deck on ferries which also carry passengers, all the front windows, where leading to passenger spaces, are to be provided with storm covers. Storm covers should also be provided such that 25 per cent of the side windows may be protected at any one time.

#### Scuppers and Discharges

**3531** Scuppers and discharges leading overboard from spaces below the main vehicle deck or from enclosed spaces on or above the vehicle deck are to be in accordance with D 2811 to D 2820.

In an enclosed 'tween deck space on the main vehicle deck, which is provided with a drencher fire extinguishing system, scuppers of not less than 150 mm diameter are to be provided port and starboard, spaced not more than 9150 mm apart. The capacity of the scuppers may require to be increased, dependent on the discharge rate of the drencher system.

The drainage arrangements of enclosed 'tween deck spaces on the main vehicle deck in ships with low freeboards are to be specially considered.

Controls which may be fitted on valves incorporated in discharges from the main vehicle deck are to be accessible at all times. Where an enclosed 'tween deck space on the main vehicle deck is provided with a drencher fire extinguishing system, such controls are to be operable from spaces above the main vehicle deck and protected from the vehicle space.

In a 'tween deck space on the main vehicle deck which is not totally enclosed, scuppers or freeing ports are to be provided consistent with the requirements of D 2804 to D 2810.

#### Protection of Crew

**3532** Bulwarks or guard rails are to be provided at the boundaries of exposed main and superstructure decks. Bulwarks are not to be less than 1 m high, and constructed as required by D 2802 and D 2803. Freeing area to be provided in accordance with the requirements of D 2804 to D 2810, but may be specially considered in relation to the height of the deck above the load waterline. Guard rails are to consist of not less than three courses, the uppermost rail being not less than 1 m above the deck. The opening below the lowest course is not to exceed 230 mm. The other courses are not to be more than 380 mm apart.

**3533** Lifelines or hand rails, or both, are to be so arranged as to provide safe access between working areas and living quarters.

#### SCANTLING REDUCTIONS FOR CERTAIN RESTRICTED SERVICE FERRIES

##### General

**3534** The scantling reductions in paragraphs 3535 to 3541 apply to ferries with class notations restricting their service to those areas listed below or to equivalent sea areas. Details of the service areas required should be submitted at the same time as plans are forwarded for consideration.

- e.g. (a) English Channel.
- (b) North Sea south of a line from Great Yarmouth to the River Elbe.
- (c) Queen Charlotte Sound.

##### Longitudinal Strength

**3535** Still water bending stresses up to a maximum of

$$\frac{85,3}{C_b + 0,20} \text{ N/mm}^2 \quad \left( \frac{8,7}{C_b + 0,20} \text{ kgf/mm}^2 \right)$$

will be accepted, where  $C_b$  is as defined in D 301.

##### Scantlings

**3536** The keel thickness for 0,4L amidships is to be not less than:—

$$\left( 3,5 + \frac{L_1}{10} \right) \sqrt{k} \text{ mm}$$

nor less than that of adjacent shell plating. For definitions of symbols, see D 501.

At ends, the keel thickness may be reduced by 25 per cent from the above value, but is still not to be less than that of the adjacent shell plating.

**3537** Bottom and side shell minimum thickness at ends may be taken 20 per cent less than that required by D 506, but is in no case to be less than 6 mm.

**3538** The thickness of double bottom centre girders may be reduced by 10 per cent, and the thickness of double bottom side girders and floors may be reduced by 5 per cent, from the values required by D 9, but is in no case to be less than 6 mm.

**3539** The thickness of bulkhead plating for peak tanks and deep tanks, other than the collision bulkhead, may be reduced by 0,5 mm, and the modulus of bulkhead stiffeners, swedges, corrugations and girders may, in general, be reduced by 20 per cent from the values required by D 19.

**3540** For deck beams under baggage spaces the value of  $h$  used in D 809 may be taken as half the deck height, i.e. equivalent to a stowage rate of 2,78 m<sup>3</sup>/tonne to the full deck height.

Deck beams under accommodation decks may be derived by direct calculation, see D 2516, using a stress of  $123,6 \frac{\text{N}}{\text{mm}^2} \left( \frac{12,6}{\text{k}} \frac{\text{kgf}}{\text{mm}^2} \right)$  in association with a distributed load as given in Table D 35.1.

TABLE D 35.1

## LOADING OF ACCOMMODATION DECKS

DECK	LOADING	
	kN/m <sup>2</sup>	tonne-f/m <sup>2</sup>
Lower decks	5,69	0,58
Strength deck	5,69	0,58
1st tier above strength deck	3,43	0,35
2nd tier above strength deck and higher	2,26	0,23

## Equipment

**3541** Equipment may be derived from Table D 34.1 using the requirements for one grade below that derived from D 3403 except that, in general, only two bower anchors need be carried on board and the stream anchor may generally be omitted.

## Scantlings for Specially Sheltered Waters Ferries

**3542** Ferries intended to operate in specially sheltered waters should, in general, be constructed to the requirements laid down in the Society's *Rules for Inland Waterways Vessels*.



## OIL TANKERS

**Section 40****GENERAL****Application**

**4001** The following Rules apply to ships classed 100A1 oil tanker having a length not exceeding 250 m. They also apply, in general, to ships classed 100A1 oil tanker having lengths exceeding 250 m, but the Society may modify the requirements as written where this is considered to be necessary (*see for example* 4005).

The scantlings and arrangements of tankers intended for cargoes other than petroleum will be specially considered in relation to the nature and density of the cargo.

Sections D 1 to D 34 apply to tankers except as otherwise required by the following Rules.

**Method of Construction**

**4002** The following Rules and Tables give requirements for welded construction.

**Structural Design**

**4003** The Rules apply to single deck tankers over 90 m in length with machinery aft and having two or more longitudinal bulkheads.

The bottom and deck are to be framed longitudinally in the cargo tank spaces; the Rules assume longitudinal framing at the sides and longitudinal bulkheads where the length of the ship exceeds 200 m, but alternative designs will be considered.

**4004** The length of a tank is not to exceed 0,2L. When the length exceeds 0,1L or 15 m, whichever is the greater, a transverse wash bulkhead is to be fitted at about the mid-length of the tank.

**4005** The scantlings of structural items may be determined using direct calculation. Where the length of the ship exceeds 250 m, the arrangements will be specially considered and the Society may require certain scantlings to be assessed by direct calculation. In such cases the calculations are to be submitted for approval.

**Loading**

**4006** Any dry tanks, or tanks intended for water ballast only and thus empty in the loaded condition, are to be indicated on the plans submitted for approval and the arrangements are to be such that these tanks cannot be used for any other purpose.

**4007** In order to guard against high stresses being imposed through an unsatisfactory cargo or ballast loading it is recommended that tankers be supplied with an approved instrument for determining suitable loading.

**Grades of Steel**

**4008** Where the seams and butts are welded, steel of Grades B and D (*see* Table P 2.2) will generally be required for the parts of the structure as detailed in Table D 40.1.

**4009** In general, strakes of Grade E steel are to be arranged as in Table D 40.2.

The fore and aft extent of the Grade E strakes is to be as follows:—

- (a) Sheerstrake and deck plating from within the poop to 0,2L forward of amidships.
- (b) Bottom and bilge plating for 0,4L amidships.

The breadth of each strake is not to be less than 1525 mm, except that the bilge strake shall not be less than 1835 mm.

**Cofferdams and Below Deck Passages or Tunnels**

**4010** Cofferdams are to be provided at the forward and after ends of the oil cargo spaces; cofferdams are to be at least 760 mm in length and are to cover the whole area of the end bulkheads of the cargo spaces.

Pump rooms or water ballast tanks will be accepted in lieu of a cofferdam. An oil fuel bunker will also be accepted provided the bulkhead between it and the cargo tank is completely welded.

Where a compartment or tank such as a fore peak tank forms the forward cofferdam, access is to be from the open deck. Alternatively, the space containing the access must conform to the requirements of M 16. Diesel or electrically driven pumps should not be sited in the space containing the access. (The attention of the Owners should be drawn to the Suez Canal Authority's requirement that only pump rooms or water ballast tanks can be accepted in lieu of a cofferdam.)

A cofferdam is also to be arranged between a cargo oil tank and accommodation spaces, and between cargo oil tanks and spaces containing electrical equipment, *see also* M 16. Where the bridge 'tween deck acts as a cofferdam, any access to this 'tween deck from the deck above is to be from the open deck, *see also* M 1625.

TABLE D 40.1

ITEM	GRADES OF PLATING		EXTENT
	Thickness greater than 20,5 mm but not exceeding 25,5 mm	Thickness greater than 25,5 mm	
<b>AMIDSHIPS</b>			
Sheerstrake ... ..	B	D	<div><div><div>Where <math>L = 155</math> m and below for <math>0,3L</math> amidships</div><div>Where <math>L = 215</math> m and above for <math>0,4L</math> amidships</div><div>Intermediate values by interpolation</div></div><div>For deck items, the forward limit must extend at least 3 m forward of the bridge front when a midship bridge is fitted</div></div>
Strength deck stringer ... ..			
Strength deck plating ... ..			
Bottom shell to upper turn of bilge*			
Top and bottom strake of longitudinal bulkhead ... ..			
Longitudinals of slab type cut from plates on:—			
(i) Deck and bottom shell ... ..			
(ii) Side shell and longitudinal bulkheads for $0,1D$ from deck and bottom ... ..			
Through brackets for deck and bottom longitudinals and also for longitudinals on side shell and longitudinal bulkheads for $0,1D$ from deck and bottom ... ..			
Webs of deck and bottom longitudinals and girders ... ..			
Face flats of deck and bottom longitudinals and girders ... ..			
<b>CLEAR OF AMIDSHIPS</b>			
Sheerstrake	B	D	Extended forward to cover any pump room openings
Strength deck stringer			
Strength deck plating			
Strength deck plating	—	D	
Bottom shell plating to upper turn of bilge			
Sheerstrake	—	D	
Strength deck stringer			
*Keel plate is to be same Grade as adjacent bottom shell plating			



TABLE D 40.2

LENGTH L		GRADE E STRAKES
Exceeding	Not exceeding	
metres 215	metres 230	Bilge strake
230	245	{ Bilge strake Sheerstrake
245	260	{ Bilge strake Sheerstrake Bottom strake in way of longitudinal bulkhead
260		{ As for tankers over 245 m with the addition of the keel, <i>see</i> Note. The deck strake in way of the longitudinal bulkhead is also to be Grade E unless the top strake of the bulkhead is of a grade not less than that of the deck, as fitted. (This is not to be taken as a relaxation of the requirements of D 120 and Table D 40.1.)

NOTE. Where no continuous centreline girder is fitted, the keel may be Grade D, provided the bottom plating is Grade D.

Passages or tunnels passing through, or adjacent to, a cargo oil tank and not separated from it by a cofferdam are to be provided with mechanical ventilation, and any access is to be from the open deck.

Where slop tanks are fitted in combined ore/oil carriers, they are to be surrounded by cofferdams which are capable of being flooded, except where the adjacent space is used as a pump room, fuel tank or cargo tank for oil or water ballast only.

#### Freeing Arrangements and Gangway

**4011** Ships with bulwarks are to have open rails fitted for at least half the length of the exposed part of each well.

A strong permanent fore and aft gangway is to be fitted at the level of the superstructure decks. Where there is no accommodation forward, the gangway between the bridge and forecastle may be omitted and where there is no midship erection and all accommodation, etc., is aft, the gangway may be omitted entirely. Arrangements are, however, to be made to give safe access to the fore end of the ship.

#### Submission of Plans

**4012** In addition to the plans required by D 110, plans showing the construction of the transverse and longitudinal oiltight bulkheads, end connections for all longitudinals and other framing members, the structure at the ends of the

ship, deckhouses protecting machinery casings and arrangements at the junction of transverse and longitudinal framing are also to be submitted.

A plan showing the arrangement and sequence of erection of the fabrication units is to be submitted.

**4013** The information required by D 3 is to be forwarded when the midship section is submitted.

#### Fittings in Tanks

**4014** Ladders, pipe hangers and other fittings in the cargo tanks and pump rooms are to be securely fastened to the structure.

For scantlings of scuppers passing through tanks, *see* D 2815.

#### Aluminium Fittings and Paint

**4015** Aluminium or aluminium alloy is not to be used for the covers of tank access openings, tank cleaning openings nor scaffold wire adjustment openings in oil cargo tanks.

*See* D 213 concerning the use of paint containing aluminium in ships carrying oil cargoes.

#### Protection of Steelwork

**4016** For the requirements for protection of steelwork and for scantling allowances when a corrosion control system is fitted, *see* D 2.

#### Maximum and Minimum Face Areas

**4017** The area of material in the face plate of any transverse, web, stringer or girder is not to exceed:—

$$\frac{d_w t_w}{150} \text{ cm}^2$$

The face area is to be not less than:—

$$(a) \text{ bottom centreline girder } \frac{I d_w}{60} \text{ cm}^2$$

$$(b) \text{ other transverses, girders, etc., } \frac{I d_w}{240} \text{ cm}^2$$

where  $I$  = distance between docking or tripping brackets, in metres,

$d_w$  = depth, in mm, of the web of the section,

$t_w$  = thickness, in mm, of the web of the section.

#### Minimum Thickness

**4018** For ships up to 200 m in length no part of the structure within the range of the cargo tanks is to be less in thickness than:—

$$t_{\min.} = 6,85 + 0,024L \text{ mm}$$



However, where  $L$  exceeds 200 m, the minimum thickness for non-primary members is to be 11,5 mm, but the thickness of transverses, girders, webs, stringers, cross ties and bulkhead plating is to be not less than:—

$$t_{\min.} = 9,5 + 0,01L \text{ mm}$$

These minima also apply to cofferdams at the ends of, or between, cargo tanks, but (except as indicated below) not to pump rooms.

In pump rooms the minimum thicknesses apply to shell, decks, longitudinal bulkheads and to the bottom, side, deck and bulkhead longitudinals.

For other items solely within these spaces, the minimum derived from the formulæ may be reduced by 1,0 mm.

## Section 42

### DECKS AND DECK OPENINGS

#### Symbols

4201

$L$  = length of ship, in metres,

$L_1$  = length of ship, in metres, but need not be taken as greater than 190 m,

$B$  = moulded breadth, in metres,

$D$  = moulded depth, in metres, to deck at side amidships,

$d$  = moulded draught, in metres, but is not to be taken as less than 0,05 $L$ ,

$s$  = spacing of longitudinals, in mm, but is not to be taken as less than

$$470 + \frac{L_1}{0,6} \text{ mm,}$$

$k$  = higher tensile steel factor, *see* D 116.

$M_D$  = actual deck modulus but is not to be taken greater than 1,5  $M_{D1}$ ,

$M_{D1}$  = Rule deck modulus from D 3,

$$F_D = \frac{M_{D1}}{M_D}$$

#### Strength Deck

4202 The thickness of deck plating amidships is to be that necessary to give the section modulus required by D 3, but is not to be less than:—

$$t = \frac{s}{900} \left( 7 + \frac{L_1}{17} \right) \sqrt{\frac{F_D}{k}} \text{ mm}$$

The midship thickness is to be maintained for 0,4 $L$  amidships and is to be gradually tapered to the end thickness. *See* Fig. D 4.1. The midship thickness may be required over an increased extent if shown to be necessary by the bending moment curves.

4203 The thickness at the poop front is to extend into the poop for a distance at least equal to one-third the breadth  $B$ .

Where the machinery opening extends forward beyond a point one-third of the breadth  $B$  abaft the poop front, and the width of the casing exceeds one-half the breadth of the ship at the poop front, the thickness of deck plating may require to be increased. The forward corners of the casing opening are to be well rounded.

4204 The thickness of the stringer plate at the ends of the bridge is to be increased by 20 per cent.

If the poop front extends within 0,25 $L$  from amidships the stringer plate at the break is to be increased by 20 per cent. No increase is required if the poop front is 0,3 $L$  from amidships or greater. The increase at intermediate lengths is to be obtained by interpolation and is to be applied to the tapered thickness of the stringer plate.

#### End Thickness

4205 The thickness of deck plating for 0,1 $L$  from the ends is not to be less than:—

$$6 + \frac{L}{48} \text{ mm}$$

Where no forecastle is fitted, and  $s > 610$  mm, the thickness derived as above is to be increased by a frame space factor,

in the ratio  $h_1 \sqrt{\frac{s}{610}}$  for 0,1 $L$  from forward,

where  $h_1 = \frac{D + 2,3 - d}{\text{actual deck height at F.P.}}$

$h_1$  need not be taken greater than 1,0, and deck height at F.P. is to be measured above summer load waterline. In no case, however, on ships with no forecastle is the thickness to be less than that required by D 1713.

4206 If a stringer angle is fitted, in way of the cargo tanks and for at least one-third of the breadth  $B$  within the poop, it is to have 150 mm flanges when the length  $L$  does not exceed 137 m, 180 mm flanges for lengths exceeding 137 m and not exceeding 170 m, and 200 mm flanges above 170 m. The thickness is to be that of the sheerstrake or stringer whichever is less. Alternative connections will be specially considered.

If the stringer angle is cut at the scuppers, compensation is to be provided. *See also* D 4310.



**4207** Where a rounded sheerstrake is incorporated the radius should, in general, not be less than 15 times the thickness. The radius should be made by careful cold rolling or bending. Where Grade E plates are subjected to severe cold working or where local heating of the plates is adopted, the plates may require to be re-normalized.

#### Lower Decks

**4208** The scantlings and arrangements of lower decks are to be as required by D 4, D 6, D 8, D 13 and D 14.

**4209** Abrupt discontinuities at the ends of lower decks and flats are to be avoided by suitable tapering of the stringer plates or by fitting large brackets.

#### Deck Openings

**4210** Openings in the deck are to be kept to the minimum number consistent with operational requirements. Openings to cargo oil tanks are not to be located in enclosed spaces.

Plate panels in which openings are cut are to be adequately stiffened, when necessary, against compression and shear buckling.

The corners of all openings are to be well rounded and the edges dressed smooth.

#### Edge Reinforcement

**4211** Where the stress concentration factor in way of the opening exceeds 2,4, edge reinforcement is generally to be fitted. This is normally to be in the form of a spigot of adequate dimensions but alternative arrangements will be considered.

Alternatively, the shape of the opening is to be such that a stress concentration factor of 2,4 is not exceeded.

In this respect, reinforcement will not, in general, be required in way of:—

- (a) elliptical openings having their major axis fore and aft and a ratio of length to breadth not less than 2 to 1,
- (b) openings of other shapes, provided it has been shown by suitable tests that the stress concentration factor does not exceed 2,4.

Circular openings of diameter up to 325 mm will also be accepted provided that they are situated at such a distance from any other opening that there is an intervening width of plating of not less than five times the diameter of the smaller of the two openings.

#### Sectional Area Compensation

**4212** Where, within the 0,5L amidships, deck openings have a total breadth, between any two adjacent transverse, exceeding 6k per cent of the width of the deck plating, compensation is to be fitted to restore the excess. The compensation is generally to be by means of increased deck plate thickness but other proposals may be considered.

Where a deck longitudinal is cut, compensation is to be arranged to ensure full continuity of strength.

The area of any edge reinforcement which may be required is not to be taken into account in determining the required sectional area of compensation.

**4213** Increased scantlings may also be required where openings are close to breaks of superstructure or other areas of high stress in any location on the ship.

#### Tank Access Hatchways

**4214** Attention is drawn to IMCO Resolutions concerning safe access to and working in large tanks.

**4215** Oiltight hatchways are to be kept to the minimum size required to provide reasonable access and ventilation. Where tanks are large or subdivided by wash bulkheads additional hatchways may be required. In determining the size and location of hatchways, consideration should be given to the handling of materials and staging for maintenance in the tank.

The size and location of hatchways should take into account access for personnel wearing breathing apparatus and removal of injured personnel (possibly on a stretcher) from the bottom of the tank.

**4216** The height of hatch coaming is generally not to be less than 600 mm, measured above the upper surface of the deck. Consideration will, however, be given to reduction of this height where permitted by the regulations of the National Authority of the country in which the ship is to be registered.

The coaming height is to be increased where necessary due to sheer or camber to ensure that the top of the hatchway is above the highest point of the tank.

The height of coaming may also require to be increased if this is shown to be necessary by the floatability calculations required by the *International Convention on Loadlines 1966*.

**4217** The coaming plate thickness is not to be less than 10 mm but may require to be increased and edge stiffening fitted where the coaming height exceeds 600 mm.



**4218** Unstiffened plate covers are not to be less than 12,5 mm in thickness.

Where the area of the cover exceeds 1,2 m<sup>2</sup>, increased plate thickness may be required or stiffening fitted.

**4219** Unstiffened covers are to be secured by fastenings spaced not more than 600 mm apart on circular hatchways. On rectangular hatchways the spacing of fastenings is generally not to exceed 450 mm but not more than 230 mm from the corners.

The arrangement of fastenings on stiffened hatchway covers and covers of special design will be specially considered.

**4220** Where the cover is hinged, adequate stiffening of the coaming and cover in way of the hinge is to be provided. In general, hinges are not to be used as securing devices for the cover.

**4221** The hatch cover packing material is to be compatible with the cargoes to be carried and is to be efficiently held in place.

#### Aluminium Alloy

**4222** Aluminium alloy is not to be used for the covers of any openings to tanks.

#### Other Materials

**4223** Consideration will be given to the use of materials other than steel for covers to openings where this is permitted by the regulations of the National Authority of the country in which the ship is to be registered.

Details of the properties of the material, the design of the cover and the method of manufacture are to be submitted for approval.

#### Small Openings

**4224** Small openings for tank cleaning, ullage plugs and similar purposes may be closed by manhole covers which are to be not less than 12,5 mm in thickness and secured by studs not more than 100 mm apart. Studs are to be arranged in a ring of suitable width and thickness attached to the deck, and are not to penetrate the deck plating.

Alternative arrangements will be considered.

#### Access to Spaces other than Cargo Tanks

**4225** Access to clean ballast or dry tanks and to cofferdams may be either by access hatch or by manhole generally complying with the preceding requirements.

Hatchway covers to dry cargo or store spaces are to comply with the requirements of D 26.

### Section 43

#### SHELL PLATING

#### Symbols

##### 4301

$L$  = length of ship, in metres,

$L_1$  = length of ship, in metres, but need not be taken as greater than 190 m,

$L_2$  = length of ship, in metres, but need not be taken as greater than 250 m,

$B$  = moulded breadth, in metres,

$D$  = moulded depth, in metres, to deck at side amidships,

$d$  = moulded draught, in metres,

$s$  = spacing of frames or longitudinals, in mm, but is not to be taken less than  $s_b$

$s_b$  = standard spacing, in mm, of frames or longitudinals, and is to be taken as:—

(a) For  $0,05L$  at ends

$s_b = 610$  mm.

(b) Elsewhere

$s_b = 470 + \frac{L_2}{0,6}$  mm

but forward of  $0,20L$  from the F.P.,  $s_b$  is not to exceed 700 mm,

$S$  = spacing of stringers, in mm,

$R$  = bilge radius, in mm,

$t$  = plate thickness, in mm,

$M_{B1}$  = Rule modulus at keel, from D 3,

$M_B$  = actual modulus at keel, but is not to be taken greater than  $1,5 M_{B1}$ ,

$M_D$  = actual deck modulus, but is not to be taken greater than  $1,5 M_{D1}$ ,

$M_{D1}$  = Rule deck modulus from D 3,

$F_B = \frac{M_{B1}}{M_B}$

$F_D = \frac{M_{D1}}{M_D}$

$F_M = F_B$  or  $F_D$  whichever is the greater,

$k$  = higher tensile steel factor, see D 116.

#### Bottom Shell and Keel

**4302** The thickness of bottom shell plating amidships is to be that necessary to give the section modulus required by D 3, but is not to be less than:—

$$t = \frac{s}{900} \left( 7 + \frac{L_1}{17} \right) \sqrt{\frac{F_B}{k}} \text{ mm}$$



$$\text{or } t = 0,0063 s \sqrt{\frac{dk}{2 - F_B}} \text{ mm}$$

whichever is the greater.

$d$  is not to be taken as less than  $0,05L$ .

The midship thickness is to be maintained for  $0,4L$  amidships and is to be gradually tapered to the end thickness. The midship thickness may be required over an increased extent if shown to be necessary by the bending moment curves.

**4303** The width and thickness of the keel over the whole length are not to be less than the values derived from the following formulæ, nor is the thickness to be less than that of the adjacent shell plating.

Width =  $70B$  mm but need not exceed  $1800$  mm

$$\text{Thickness} = \left(6 + \frac{L_1}{10}\right) \sqrt{k} \text{ mm}$$

#### Bilge Plating

**4304** The thickness of the bilge plating is not to be less than that determined for the bottom shell from 4302.

Where no longitudinals are fitted except for those at the upper and lower extremity of the bilge radius, then in addition to the required minimum thickness derived from 4302 the bilge thickness must not be less than  $\frac{R}{165k}$  and the spacing of transverses or equivalent bilge brackets must not exceed

$$8 \times 10^6 \frac{t^2}{DR} \sqrt{\frac{t}{R}} \text{ mm}$$

Where intermediate bilge brackets are fitted between transverses on vessels with no bilge longitudinals, then not less than two such brackets should be fitted.

#### Side Shell

**4305** Within  $0,4L$  amidships the thickness of side shell plating is not to be less than:—

(a) with longitudinal framing,

$$t = \frac{s}{900} \left(7 + \frac{L_1}{17}\right) \sqrt{\frac{F_M}{k}} \text{ mm}$$

nor is the plating thickness to be less than

$$0,0049 s \sqrt{dk} \text{ mm}$$

above  $\frac{D}{2}$  from base line, or

$$t = 0,0059 s \sqrt{\frac{dk}{2 - F_B}} \text{ mm}$$

at upper turn of bilge. Intermediate values by interpolation.

The thickness of side shell plating need not exceed that determined from 4302, using the spacing of the side shell longitudinals.

(b) With transverse framing

(i) Within  $\frac{D}{4}$  from deck but see 4308:

$$t = \frac{s}{1180} \left(1 + \left(\frac{s}{S}\right)^2\right) \left(10 + \frac{L_1}{12}\right) \sqrt{\frac{F_D}{k}} \text{ mm}$$

$$\text{or } t = 0,0049 s \sqrt{dk} \text{ mm}$$

whichever is the greater.

(ii) Within  $\frac{D}{4}$  from mid-depth:

$$t = \frac{s}{1000} \left(7 + \frac{L_1}{17}\right) \sqrt{\frac{F_M}{k}} \text{ mm}$$

$$\text{or } t = 0,0059 s \sqrt{dk} \text{ mm}$$

whichever is the greater.

(iii) Within  $\frac{D}{4}$  from bottom:

$$t = \frac{s}{1180} \left(1 + \left(\frac{s}{S}\right)^2\right) \left(10 + \frac{L_1}{12}\right) \sqrt{\frac{F_B}{k}} \text{ mm}$$

$$\text{or } t = 0,007 s \sqrt{\frac{dk}{2,5 - 1,5 F_B}} \text{ mm}$$

whichever is the greater.

**4306** The midship thickness of side shell is to be gradually tapered to the end thickness. See 4307.

#### End Thickness

**4307** The thickness of shell plating for  $0,05L$  at the fore end and  $0,1L$  at the aft end is not to be less than:—

$$\left(6,5 + \frac{L}{30}\right) \sqrt{\frac{s}{s_b}} \text{ mm}$$

#### Sheerstrake

**4308** The width of sheerstrake for  $0,5L$  amidships is not to be less than  $0,1D$  and the thickness is not to be less than that of the deck plating or side shell, whichever is the greater. Where the side shell is transversely framed up to deck at side, the sheerstrake is also not to be less than the thickness required by the formulae given in D 403 (b).

At ends the thickness of sheerstrake may be the same as the side shell.

**4309** The thickness of the sheerstrake is to be increased 20 per cent at the ends of the bridge, but this increase is not required if the bridge does not extend to the ship's side.

If the poop front at side extends within 0,25L from amidships the sheerstrake at the break is to be increased by 20 per cent. No increase is required if the poop front at side is 0,3L from amidships or greater. The increase at intermediate positions is to be obtained by interpolation and is to be applied to the tapered thickness of the sheerstrake.

**4310** The upper edge of the sheerstrake is to be dressed smooth and kept free of isolated welded fittings or connections. In ships over 150 m in length scupper openings are not to be cut above the deck within 0,5L amidships or in way of breaks of superstructures.

Where a rounded sheerstrake is adopted, the welding of fairleads or other fittings to this plate is to be reduced to a minimum and details are to be submitted for approval.

#### Superstructures

**4311** The thickness of plating forming the sides of superstructures outside 0,5L amidships is generally not to be less than:—

(a) Forecastle

$$t = \left(7 + \frac{L}{50}\right) \sqrt{\frac{s}{s_b}} \text{ mm}$$

(b) Poop

$$t = \left(6 + \frac{L}{60}\right) \sqrt{\frac{s}{s_b}} \text{ mm}$$

The thickness of plating forming the sides of superstructures extending within 0,5L amidships will be considered. See also D 307.

#### Openings in Shell

**4312** Sea inlets in pump rooms situated within 0,5L amidships, are, if practicable, to be fitted clear of the bilge radius. All openings are to be arranged so as to minimize discontinuity of transverse frames, longitudinals or bilge keels. Compensation is to be provided for all openings within 0,5L amidships and may be required for openings in the vicinity of the poop front. The compensation should, if possible, take the form of an insert plate rather than a doubler.

If openings are not circular or oval the corners are to be rounded with as large a radius as practicable.

#### Bilge Keels

**4313** Where bilge keels are fitted, it is desirable that they be attached to a continuous flat bar which may be welded to the shell. Scallops are to be arranged in way of welded butts in the flat bar. Alternative arrangements, or arrangements omitting the flat bar, will be specially considered.

Bilge keels are to be gradually tapered at their ends and are not to finish on an unstiffened panel.

### Section 44

#### BOTTOM, SIDE AND DECK LONGITUDINALS

##### Symbols

**4401**

$L_1$  = length of ship, in metres, but need not be taken as greater than 190 m,

$D$  = moulded depth, in metres,

$S$  = span, in metres, measured between transverse or from transverse to "span point" (minimum value 2,5 m),

$s$  = spacing of longitudinals, in mm,

$h$  = distance of longitudinal below deck at side, in metres,

$h_1$  =  $h$ , but is in no case to be taken less than:—

$$\frac{L_1}{56} \text{ m}$$

$k$  = higher tensile steel factor, see D 116,

$M_{B1}$  = Rule modulus, at keel, from D 3,

$M_B$  = actual modulus, at keel, but is not to be taken greater than 1,2  $M_{B1}$ ,

$$F_B = \frac{M_{B1}}{M_B}$$

$c$  = 1,0 at  $\frac{D}{2}$  and above, and

$$c = \frac{910}{2550 - 1640F_B} \text{ at base line.}$$

Intermediate values of  $c$  by interpolation.

##### Scantlings

**4402** The scantlings of longitudinals within the range of cargo tanks are not to be less than required by the following formula:—

$$\frac{I}{y} = 0,01355 s S^2 K_1 \text{ cm}^3$$

where  $K_1$  values are as given in Table D 44.1.



In the case of deck longitudinals, however, the modulus may be gradually tapered forward of 0,2L forward of amidships, to a value of 80 per cent of the midship value (corrected if necessary for span and spacing), or to the value required by D 602, whichever be the greater.

The section modulus given is that of the longitudinal and associated plating.

TABLE D 44.1  $K_1$  VALUES

ITEM	$K_1$
Deck longitudinals	$\frac{L_1}{56}$
Side longitudinals above $\frac{D}{2}$	$\frac{h_1 D}{D + 1,27 h}$
Side longitudinals below $\frac{D}{2}$	$\frac{h D c}{1,83 D - 0,38 h}$
Bottom longitudinals	$0,8 D c$

The scantlings derived from the above, using the midship thickness of plating, are to extend throughout the cargo tanks.

Where no bilge longitudinals are fitted, then if the spacing of the outermost two bottom longitudinals exceeds one-third of the bilge radius or 40 times the local shell thickness, whichever be the greater, at least two bilge brackets are to be fitted between transverses. The brackets shall be attached to the longitudinals at the upper and lower turns of bilge.

**4403** The scantlings of bilge longitudinals, where fitted, are to be graduated between those required for the bottom and lowest side longitudinals, *but see* D 4304.

**4404** Where flat bars are used for longitudinals and these are continuous at bulkheads, the thickness is not to be less than one-eighteenth of the depth; otherwise, the thickness should not be less than one-fifteenth of the depth.

Where built sections are used, the breadth of face bar is not to be less than as follows:

- (a) For longitudinals within 0,15D of base line and deck line

—symmetrical face bars

$$b_F = k_1 S \text{ mm}$$

—asymmetrical face bars

$$b_F = k_1 k_3 S \text{ mm}$$

The ratio of web depth to web thickness is not to exceed 55 : 1, i.e.  $\frac{t_W}{d}$  is not to be less than 0,0182

- (b) For longitudinals within 0,35D of mid-depth

—symmetrical face bars

$$b_F = k_2 S \text{ mm}$$

—asymmetrical face bars

$$b_F = k_2 k_3 S \text{ mm}$$

The ratio of web depth to web thickness is not to exceed 60 : 1, i.e.  $\frac{t_W}{d}$  is not to be less than 0,0167

where  $b_F$  = minimum breadth of face bar, in mm,

$k_1$ ,  $k_2$  and  $k_3$  are determined from Figs. D 44.1, D 44.2 and D 44.3,

$A_W$  = sectional area of web of longitudinal, in  $\text{cm}^2$ ,

$A_F$  = sectional area of face bar, in  $\text{cm}^2$ ,

$t_W$  = thickness of web, in mm,

$d$  = depth of web, in mm,

$S$  = span of longitudinal, in metres, but not to be taken less than 2,44 m.

NOTE. Figs. D 44.1, D 44.2 and D 44.3 represent the following formulæ:—

$$k_1 = 25 \sqrt{1 + \frac{A_W}{2 A_F} \left[ 1 - \left( \frac{20 t_W}{d} \right)^2 \right]}$$

$$k_2 = 20 \sqrt{1 + \frac{A_W}{1,66 A_F} \left[ 1 - \left( \frac{25 t_W}{d} \right)^2 \right]}$$

$$k_3 = \frac{1}{\sqrt{1 + 0,35 \sqrt{\frac{A_W}{A_F}}}}$$

#### Higher Tensile Steel

**4405** Where higher tensile steel is used, the section modulus of deck, side, bottom and inner bottom longitudinals is to be multiplied by the factor  $k$ .

The minimum breadth of face bar is to be 15 per cent greater than given by 4404. The maximum web depth to web thickness ratios given in 4404 are to be multiplied by the factor  $\sqrt{k}$ .

#### Connections

**4406** End connections of longitudinals to bulkheads are to provide adequate fixity and, so far as practicable, direct continuity of longitudinal strength.



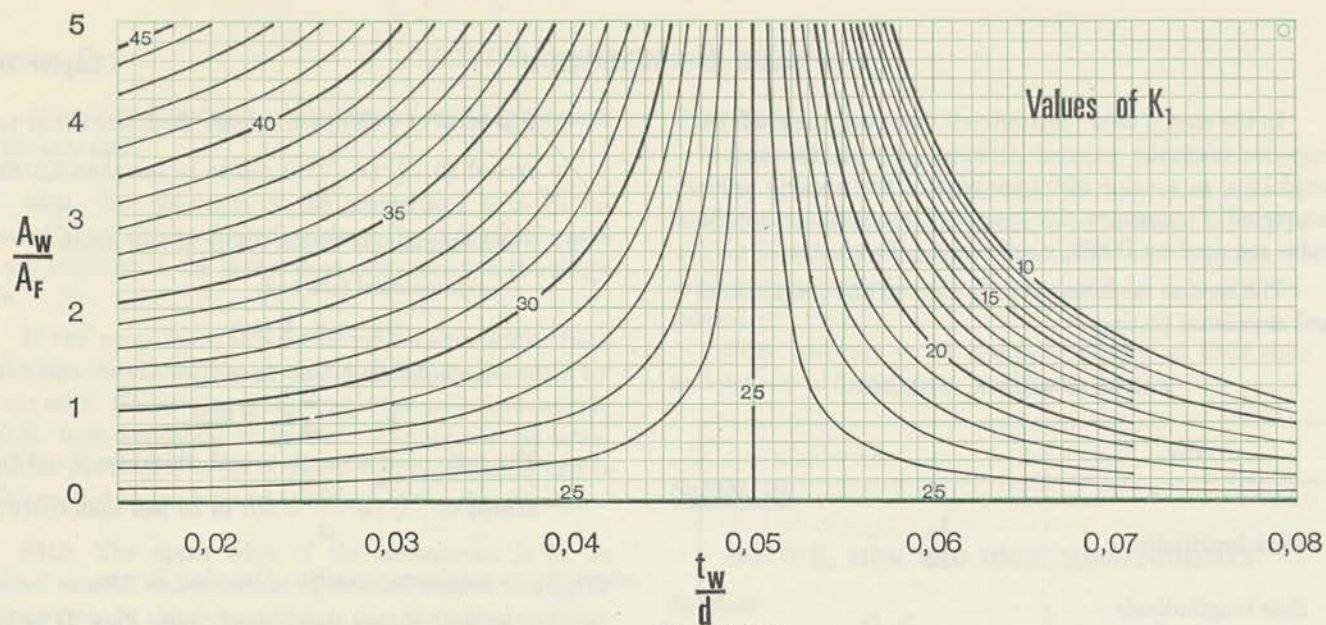


FIG. D 44.1

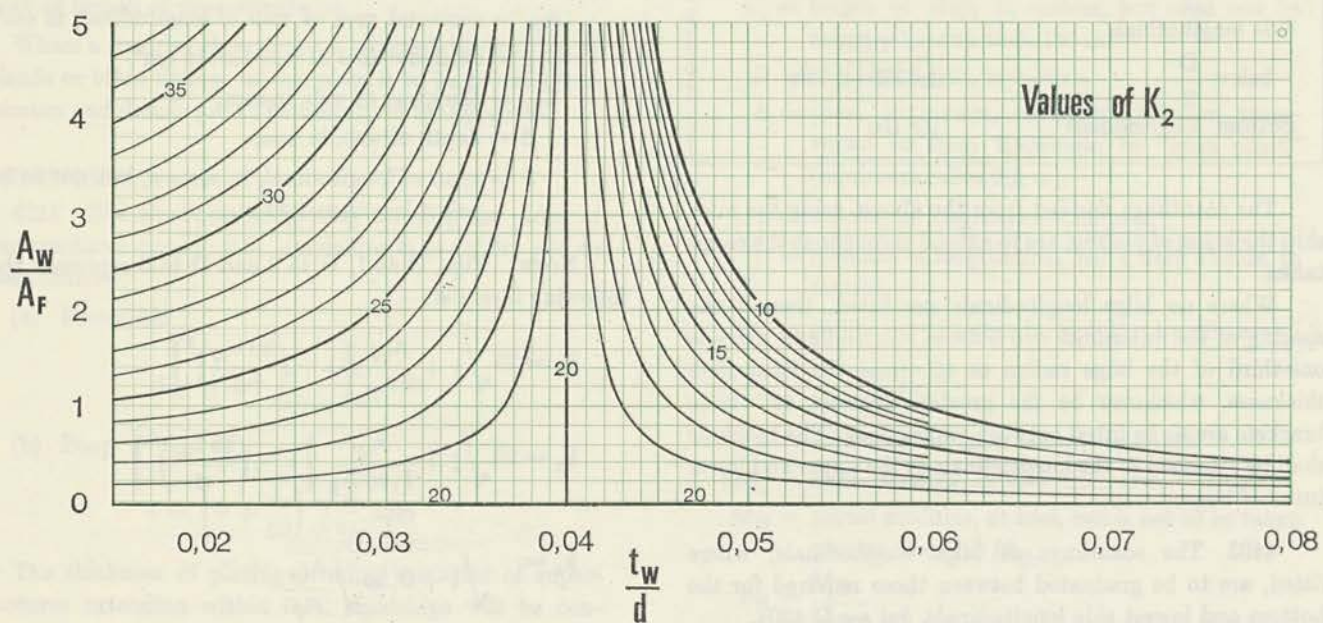


FIG. D 44.2

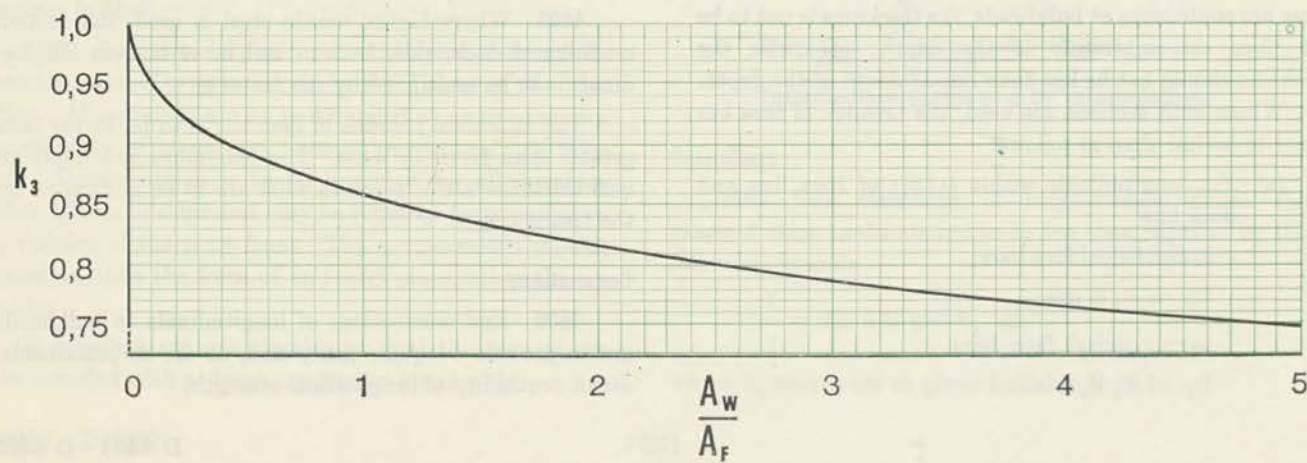


FIG. D 44.3



**4407** Where the length exceeds 190 m it is desirable that the bottom and deck longitudinals be continuous through the transverse bulkheads but alternative arrangements will be specially considered.

**4408** Longitudinals are to be connected to the transverse as required by Table D 32.4. *See also* D 5122 and D 5123.

### Openings in Longitudinals

**4409** Closely spaced scallops (*see* Fig. D 32.1) are not permitted in longitudinals within the range of cargo tanks.

Small air and drain holes, cut-outs at erection butts and similar widely spaced openings are to be kept at least 200 mm clear of the toes of end brackets, intersections with primary supporting members and other areas of high stress. All openings are to be well rounded with smooth edges.

Small circular air holes may be accepted in deck longitudinals. Cut-outs at erection butts may be semi-circular or approximately so, and a similar shape may be adopted for drain holes in longitudinals attached to mild steel plating.

Drain holes in higher tensile steel longitudinals attached to higher tensile steel plating are to be elliptical in shape or of equivalent design to minimize stress concentrations. The opening is generally to be located clear of the welded connection to the plating, but where a flush opening is essential for drainage the weld connection is to end in a soft toe.

Isolated openings need not be taken into account in calculating the section modulus of the longitudinal, provided that the depth does not exceed 10 per cent of the web depth, or 75 mm, whichever is the greater, but in no case more than 25 per cent of the depth of the longitudinal.

### Deck Longitudinals at Ends

**4410** For scantlings of deck longitudinals at ends, *see* D 602.

## Section 45

### TRANSVERSE SIDE FRAMING

#### Symbols

**4501**

D = moulded depth, in metres, to deck at side amidships,

S = span, in metres, measured between stringers or from stringer to "span point",

S = frame spacing, in mm,

h = head, in metres, from mid-point of span to deck at side measured at mid-length of tank.

### Scantlings

**4502** Where, in tankers not exceeding 200 m in length, transverse side framing is adopted in the cargo tanks, the section modulus of side frames is not to be less than:—

$$\frac{I}{y} = \frac{s h S^2}{97,5} \text{ cm}^3$$

where side transverse are fitted,

$$\text{or } \frac{I}{y} = \frac{s h S^2}{83,3} \text{ cm}^3$$

where side transverse are not fitted.

The size of the frame is to be governed by the maximum modulus derived from the above formula and is to be maintained for the full depth of the ship. The modulus given is that of the frame and associated side shell plating.

### Side Stringers

**4503** Where the depth D does not exceed 7,5 m, one side stringer is to be fitted. Where D exceeds 7,5 m but does not exceed 11 m, 2 stringers are required, and over 11 m depth, 3 stringers. For scantlings of stringers, *see* D 4703.

### Side Transverses

**4504** Where the depth D exceeds 11 m, or the distance between transverse bulkheads (whether oiltight or non-oiltight) exceeds 15 m, side transverses are to be fitted in line with the bottom transverses. The scantlings of the side transverses are to be determined in accordance with D 4607.

### Connections and End Attachments

**4505** Side frames are to be connected to the side stringers as required by Table D 32.4.

**4506** The brackets at the upper end of side frames are to be as required by D 16.

**4507** Side frames are to be efficiently connected at the lower end to stiffened brackets covering the entire round of bilge and extending at least to the first bottom longitudinal. The thickness of the bracket is to be the same as that of the transverses in the wing tank.

## Section 46

## BOTTOM, SIDE AND DECK TRANSVERSES

## Symbols

4601

L = length of ship, in metres,

D = moulded depth, in metres,

 $S_T$  = span of transverses, in metres, and to be taken as  $(b_t - 2b_e)$  metres, $b_t$  = breadth of tank, measured between faces of the vertical transverses where applicable, in metres, $b_e$  = effective bracket size, in metres, *see* D 130,

s = spacing of transverses, in metres,

n = number of continuous longitudinal girders in tank breadth,

h and l are as shown in Fig. D 46.2, in metres.

## General

4602 The spacing of transverses is not to exceed 3,6 m when the length L is 180 m or less, or  $\frac{L}{50}$  when L exceeds 180 m. Where, however, the longitudinal bulkhead is corrugated, the spacing of transverses is not to exceed 5 m.

The requirements for the bottom transverses are given in association with the following basic girder support arrangements:—

## 1. For Transverses in Centre Tanks

- (a) Bottom transverses in association with continuous centreline girder.
- (b) Bottom transverses in association with three continuous girders of equal scantling and approximately equal spacing.
- (c) Bottom transverses with intercostal centreline docking girder.

## 2. For Transverses in Wing Tanks

- (a) Bottom transverse in association with one continuous girder at about mid-span.
- (b) Bottom transverse with one intercostal girder at about mid-span.

Where any other arrangement of bottom transverses and girders is proposed these will be specially considered.

## Bottom Transverses

4603 The section modulus of the transverses, other than bottom transverses in wing tanks not fitted with struts, is to be not less than:—

$$\frac{I}{y} = 62 K_1 s D S_T^2 \text{ cm}^3$$

where  $K_1$  is a coefficient obtained from Tables D 46.1.

The section modulus of bottom transverses in wing tanks not fitted with struts will be specially considered and, in general, a direct calculation will be required.

4604 The depth of the bottom transverse is not to be less than either one-fifth of its span, between girders where fitted, or 2,5 times the depth of the slot for the bottom longitudinal whichever is the greater. The thickness of the web plate is to be such that the net sectional area of the web at any section of its length is not to be less than:—

$$A = \frac{Q_x}{F} \text{ cm}^2$$

where A = net sectional area of the web, including bracket where applicable, in  $\text{cm}^2$ ,

$Q_x$  = shear force at the actual section under consideration obtained from diagrams constructed in accordance with (a), (b) or (c) of Fig. D 46.1 in kN (tonne-f),

$$F = 8,34 (0,85).$$

4605 For web stiffening, *see* D 51.

4606 For minimum thicknesses, *see* D 4018. For geometric properties of sections, *see* D 128.

## Side Transverses

4607 The section modulus of the transverse is not to be less than:—

$$\frac{I}{y} = K_1 s h l^2 \text{ cm}^3$$

where  $K_1 = 15 \left(1 - \frac{l}{2h}\right) \left(\frac{90}{L}\right)^2$  where no cross tie fitted,

but not to be taken less than 3,72,

2,16 where one cross tie fitted,

1,88 where two or more cross ties fitted.

4608 The depth of the side transverse web is not to be less than 2,5 times the depth of the slot for the adjacent side



longitudinals and the thickness of the web is to be such that the net sectional area of the web at any section is not to be less than:—

$$A = \frac{Q_x}{F} \text{ cm}^2$$

where  $A$  = net sectional area of the web, including bracket where applicable, in  $\text{cm}^2$ ,

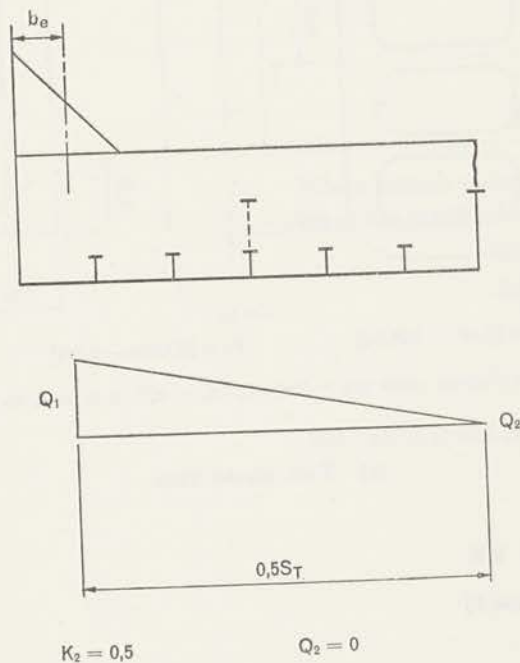
$Q_x$  = shear force at the actual section under consideration obtained from diagrams constructed in accordance with (a), (b) or (c) of Fig. D 46.2, in kN (tonne-f),

$$F = 8,34 \text{ (0,85)}.$$

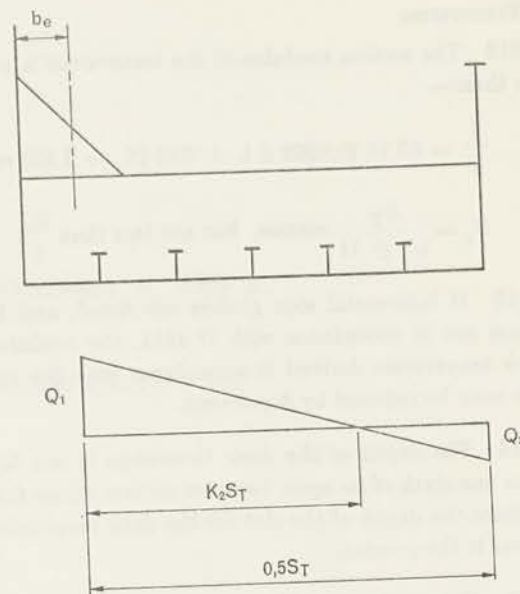
**4609** For web stiffening, see D 51.

**4610** If side transverses are tapered, the increase in depth at the bottom, and decrease at the top, is not to exceed 10 per cent of the mean depth.

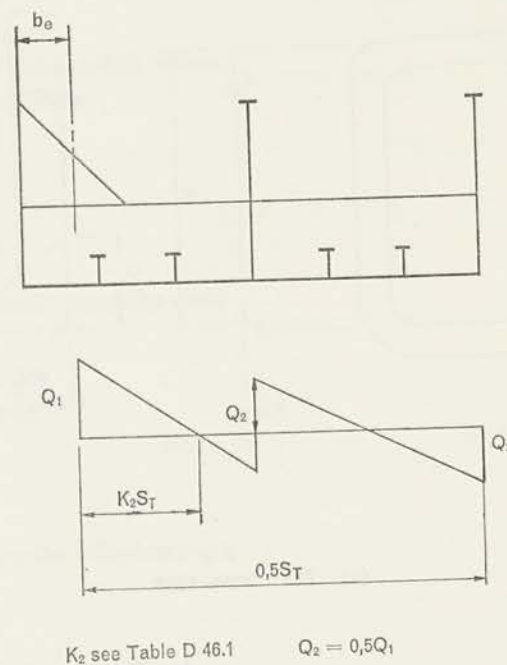
**4611** For minimum thicknesses, see D 4018. For geometric properties of sections, see D 128.



(a) BOTTOM TRANSVERSES WITH INTERCOSTAL GIRDERS



(b) BOTTOM TRANSVERSES WITH CONTINUOUS GIRDER



(c) BOTTOM TRANSVERSES WITH THREE CONTINUOUS GIRDERS

In all cases  $Q_1 = 10,05 K_2 s D S_T \text{ kN}$   
 $(Q_1 = 1,025 K_2 s D S_T \text{ tonne-f})$

FIG. D 46.1

## Deck Transverses

**4612** The section modulus of the transverses is not to be less than:—

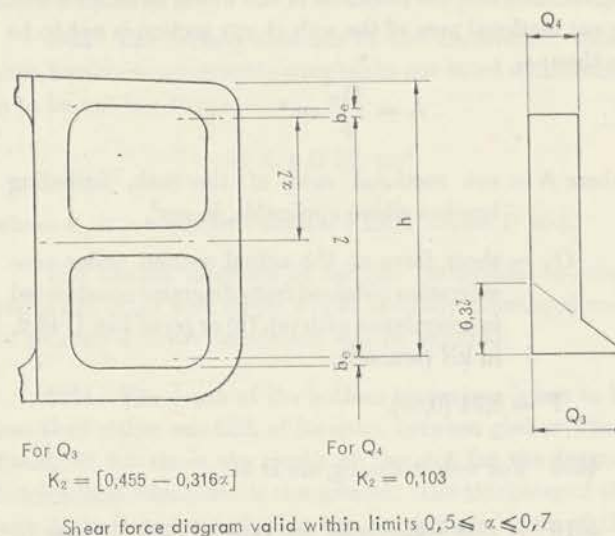
$$\frac{I}{y} = 53,75 (0,0269 s L + 0,8) (S_1 + 1,83) \text{ cm}^3$$

$$S_1 = \frac{S_T}{(n + 1)} \text{ metres, but not less than } \frac{b_t}{6}$$

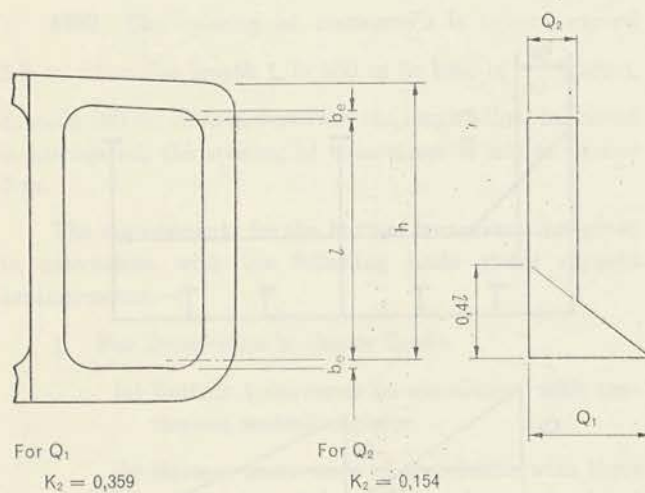
**4613** If intercostal side girders are fitted, and their scantlings are in accordance with D 4811, the modulus of the deck transverses derived in accordance with the above formula may be reduced by 5 per cent.

**4614** The depth of the deck transverse is not to be less than one-sixth of its span, between girders where fitted, or 2,5 times the depth of the slot for the deck longitudinal, whichever is the greater.

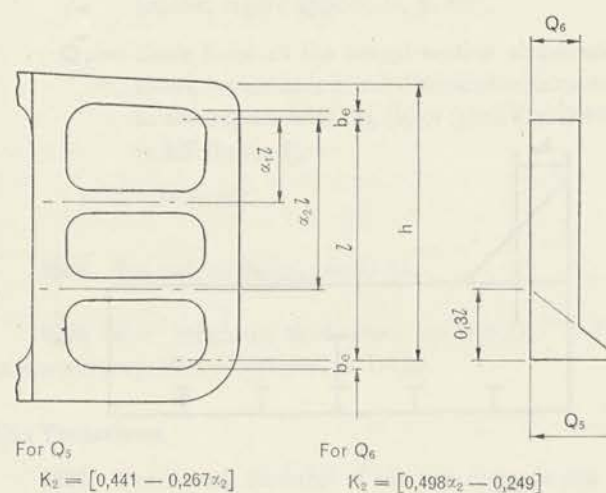
**4615** For minimum thicknesses, see D 4018. For geometric properties of sections, see D 128.



(b) ONE CROSS TIE



(a) NO CROSS TIES



(c) TWO CROSS TIES

In all cases  $Q = 9,81 K_2 h s l \text{ kN}$

( $Q = K_2 h s l \text{ tonne-f}$ )

Fig. D 46.2



TABLES D 46.1 VALUES OF COEFFICIENTS  $K_1$  AND  $K_2$ 

The following Tables are based on values of  $\alpha$  and  $\beta$  which are derived as follows:—

$$\alpha = \frac{l_T - S_G}{2s}$$

$$\beta = \frac{S_G^3 I_T}{S_T^3 I_G}$$

where  $S_G$  = span of girder, in metres, (see D 4803 for minimum value),

$S_T$  = span of transverses, in metres,

$I_G$  = inertia of girder, in  $\text{cm}^4$ ,

$I_T$  = inertia of transverses, in  $\text{cm}^4$ ,

$l_T$  = distance between support bulkheads, in metres,

$s$  = spacing of transverses, in metres.

TABLE D 46.1 (a)

Where bottom transverses with intercostal centreline docking girder are fitted:—

B.M. Coeff.  $K_1 = 0,083$

S.F. Coeff.  $K_2 = 0,50$

For Tables D 46.1 (b) and D 46.1 (c), see the following pages.

TABLE D 46.1 (b) (see continuation)

(b) 1 GIRDER 2 TRANSVERSES

GIRDER												
$\beta$	B.M. COEFF. $K_1$						S.F. COEFF. $K_2$					
	$\alpha$						$\alpha$					
	0,0	0,2	0,4	0,6	0,8	1,0	0,0	0,2	0,4	0,6	0,8	1,0
0,02	0,210	0,210	0,195	0,175	0,125	0,0	1,000	1,000	1,000	1,000	1,000	1,000
0,04	0,210	0,210	0,195	0,175	0,125	0,0	0,960	0,960	0,980	1,000	1,000	1,000
0,06	0,210	0,210	0,195	0,170	0,125	0,0	0,940	0,940	0,960	0,980	1,000	1,000
0,08	0,205	0,205	0,190	0,167	0,125	0,0	0,920	0,920	0,940	0,970	1,000	1,000
0,10	0,200	0,200	0,185	0,165	0,125	0,0	0,900	0,900	0,920	0,960	0,990	1,000
0,20	0,180	0,180	0,170	0,150	0,120	0,0	0,800	0,820	0,860	0,920	0,980	1,000
0,40	0,150	0,150	0,150	0,135	0,115	0,0	0,670	0,730	0,760	0,840	0,950	1,000
0,60	0,130	0,130	0,135	0,125	0,110	0,0	0,580	0,630	0,690	0,790	0,910	1,000
0,80	0,120	0,120	0,120	0,120	0,105	0,0	0,520	0,540	0,630	0,730	0,880	1,000
1,00	0,100	0,100	0,115	0,115	0,100	0,0	0,460	0,500	0,580	0,680	0,850	1,000

TRANSVERSES												
$\beta$	B.M. COEFF. $K_1$						S.F. COEFF. $K_2$					
	$\alpha$						$\alpha$					
	0,0	0,2	0,4	0,6	0,8	1,0	0,0	0,2	0,4	0,6	0,8	1,0
0,02	0,022	0,022	0,022	0,022	0,021	0,020	0,255	0,255	0,255	0,255	0,250	0,250
0,04	0,023	0,023	0,023	0,022	0,021	0,020	0,263	0,263	0,257	0,255	0,250	0,250
0,06	0,025	0,025	0,023	0,022	0,021	0,020	0,265	0,265	0,263	0,260	0,250	0,250
0,08	0,026	0,026	0,024	0,023	0,021	0,020	0,270	0,270	0,267	0,260	0,253	0,250
0,10	0,027	0,027	0,025	0,023	0,022	0,020	0,275	0,275	0,270	0,263	0,255	0,250
0,20	0,033	0,033	0,029	0,026	0,023	0,020	0,300	0,300	0,285	0,272	0,257	0,250
0,40	0,041	0,041	0,036	0,032	0,025	0,020	0,330	0,330	0,307	0,287	0,265	0,250
0,60	0,047	0,047	0,041	0,036	0,026	0,020	0,355	0,355	0,325	0,302	0,273	0,250
0,80	0,051	0,051	0,045	0,038	0,028	0,020	0,370	0,370	0,342	0,315	0,278	0,250
1,00	0,054	0,054	0,048	0,041	0,030	0,020	0,385	0,385	0,355	0,327	0,285	0,250

Table D 46.1 (b)



TABLE D 46.1 (b) (continued)

(b) 1 GIRDER 3 TRANSVERSES

GIRDER												
$\beta$	B.M. COEFF. $K_1$						S.F. COEFF. $K_2$					
	$\alpha$						$\alpha$					
	0,0	0,2	0,4	0,6	0,8	1,0	0,0	0,2	0,4	0,6	0,8	1,0
0,02	0,290	0,290	0,290	0,270	0,200	0,120	1,400	1,400	1,500	1,500	1,500	1,500
0,04	0,290	0,290	0,290	0,270	0,200	0,120	1,400	1,400	1,500	1,500	1,500	1,500
0,06	0,290	0,290	0,290	0,260	0,200	0,120	1,380	1,400	1,500	1,500	1,500	1,500
0,08	0,280	0,280	0,280	0,250	0,195	0,115	1,340	1,370	1,470	1,470	1,480	1,500
0,10	0,275	0,275	0,275	0,240	0,190	0,115	1,320	1,340	1,420	1,440	1,460	1,480
0,20	0,245	0,245	0,245	0,220	0,175	0,105	1,180	1,210	1,280	1,330	1,380	1,450
0,40	0,200	0,200	0,200	0,185	0,160	0,090	0,970	1,030	1,080	1,200	1,280	1,420
0,60	0,170	0,170	0,170	0,170	0,145	0,080	0,840	0,900	0,960	1,110	1,210	1,380
0,80	0,150	0,150	0,150	0,150	0,135	0,075	0,740	0,800	0,870	1,040	1,150	1,330
1,00	0,135	0,135	0,135	0,135	0,125	0,070	0,680	0,740	0,810	0,960	1,100	1,300

TRANSVERSES												
$\beta$	B.M. COEFF. $K_1$						S.F. COEFF. $K_2$					
	$\alpha$						$\alpha$					
	0,0	0,2	0,4	0,6	0,8	1,0	0,0	0,2	0,4	0,6	0,8	1,0
0,02	0,025	0,025	0,024	0,023	0,022	0,022	0,258	0,258	0,257	0,252	0,252	0,252
0,04	0,026	0,026	0,025	0,024	0,023	0,023	0,267	0,267	0,267	0,262	0,262	0,260
0,06	0,028	0,028	0,026	0,026	0,025	0,024	0,275	0,275	0,275	0,270	0,270	0,265
0,08	0,030	0,030	0,028	0,028	0,026	0,026	0,285	0,285	0,280	0,272	0,272	0,272
0,10	0,032	0,032	0,029	0,029	0,028	0,027	0,292	0,292	0,287	0,277	0,275	0,275
0,20	0,040	0,040	0,037	0,035	0,033	0,032	0,325	0,325	0,315	0,310	0,300	0,282
0,40	0,052	0,052	0,049	0,046	0,041	0,039	0,372	0,372	0,360	0,345	0,332	0,320
0,60	0,059	0,059	0,057	0,054	0,048	0,045	0,405	0,405	0,392	0,375	0,357	0,342
0,80	0,065	0,065	0,063	0,059	0,053	0,049	0,425	0,425	0,415	0,390	0,377	0,360
1,00	0,069	0,069	0,066	0,063	0,056	0,052	0,440	0,440	0,432	0,415	0,395	0,375

TABLE D 46.1 (b) (continued)

(b) 1 GIRDER 4 TRANSVERSES

GIRDER												
$\beta$	B.M. COEFF. $K_1$						S.F. COEFF. $K_2$					
	$\alpha$						$\alpha$					
	0,0	0,2	0,4	0,6	0,8	1,0	0,0	0,2	0,4	0,6	0,8	1,0
0,02	0,370	0,350	0,330	0,315	0,275	0,215	1,890	1,890	1,920	1,940	1,960	1,990
0,04	0,370	0,350	0,330	0,315	0,275	0,215	1,870	1,870	1,900	1,930	1,940	1,960
0,06	0,360	0,350	0,330	0,310	0,270	0,205	1,820	1,820	1,870	1,890	1,920	1,940
0,08	0,350	0,340	0,320	0,300	0,260	0,200	1,760	1,800	1,820	1,840	1,880	1,920
0,10	0,340	0,330	0,315	0,290	0,255	0,195	1,700	1,750	1,790	1,830	1,860	1,900
0,20	0,300	0,300	0,275	0,260	0,230	0,180	1,500	1,580	1,630	1,700	1,780	1,820
0,40	0,240	0,240	0,230	0,220	0,200	0,155	1,240	1,300	1,400	1,540	1,620	1,700
0,60	0,200	0,200	0,200	0,200	0,175	0,135	1,060	1,120	1,250	1,400	1,500	1,600
0,80	0,175	0,175	0,175	0,175	0,165	0,120	0,940	1,000	1,150	1,270	1,420	1,520
1,00	0,150	0,150	0,150	0,150	0,150	0,105	0,850	0,920	1,050	1,200	1,340	1,460

TRANSVERSES												
$\beta$	B.M. COEFF. $K_1$						S.F. COEFF. $K_2$					
	$\alpha$						$\alpha$					
	0,0	0,2	0,4	0,6	0,8	1,0	0,0	0,2	0,4	0,6	0,8	1,0
0,02	0,025	0,025	0,024	0,024	0,023	0,023	0,255	0,255	0,255	0,255	0,253	0,250
0,04	0,027	0,026	0,026	0,025	0,025	0,024	0,272	0,270	0,268	0,266	0,260	0,255
0,06	0,029	0,029	0,028	0,027	0,026	0,025	0,282	0,280	0,275	0,272	0,270	0,263
0,08	0,031	0,031	0,030	0,028	0,028	0,027	0,292	0,287	0,285	0,280	0,275	0,270
0,10	0,033	0,033	0,032	0,030	0,029	0,028	0,300	0,295	0,290	0,285	0,280	0,275
0,20	0,042	0,041	0,039	0,037	0,035	0,033	0,335	0,325	0,320	0,313	0,307	0,300
0,40	0,053	0,051	0,050	0,047	0,044	0,041	0,380	0,372	0,362	0,352	0,342	0,330
0,60	0,061	0,059	0,057	0,054	0,050	0,047	0,412	0,405	0,387	0,376	0,365	0,355
0,80	0,066	0,065	0,062	0,058	0,054	0,051	0,435	0,425	0,412	0,400	0,382	0,370
1,00	0,070	0,068	0,065	0,062	0,058	0,055	0,450	0,437	0,427	0,412	0,395	0,385

Table D 46.1 (b)



TABLE D 46.1 (b) (conclusion)

(b) 1 GIRDER 5 TRANSVERSES

GIRDER												
$\beta$	B.M. COEFF. $K_1$						S.F. COEFF. $K_2$					
	$\alpha$						$\alpha$					
	0,0	0,2	0,4	0,6	0,8	1,0	0,0	0,2	0,4	0,6	0,8	1,0
0,02	0,455	0,440	0,410	0,380	0,345	0,300	2,330	2,350	2,370	2,400	2,420	2,450
0,04	0,445	0,430	0,410	0,380	0,345	0,300	2,310	2,340	2,360	2,380	2,410	2,440
0,06	0,430	0,415	0,395	0,370	0,340	0,295	2,250	2,290	2,300	2,340	2,380	2,400
0,08	0,415	0,400	0,385	0,365	0,330	0,290	2,180	2,230	2,280	2,290	2,340	2,360
0,10	0,400	0,390	0,375	0,355	0,320	0,280	2,110	2,170	2,200	2,240	2,300	2,320
0,20	0,345	0,340	0,330	0,315	0,285	0,250	1,840	1,920	2,000	2,040	2,130	2,180
0,40	0,270	0,265	0,265	0,265	0,235	0,200	1,500	1,600	1,700	1,790	1,900	1,970
0,60	0,220	0,220	0,220	0,220	0,200	0,165	1,280	1,380	1,500	1,610	1,650	1,840
0,80	0,185	0,185	0,185	0,185	0,175	0,140	1,140	1,230	1,370	1,500	1,620	1,740
1,00	0,165	0,165	0,165	0,165	0,160	0,125	1,040	1,140	1,280	1,420	1,540	1,650

TRANSVERSES												
$\beta$	B.M. COEFF. $K_1$						S.F. COEFF. $K_2$					
	$\alpha$						$\alpha$					
	0,0	0,2	0,4	0,6	0,8	1,0	0,0	0,2	0,4	0,6	0,8	1,0
0,02	0,025	0,025	0,025	0,024	0,024	0,023	0,265	0,265	0,263	0,260	0,257	0,255
0,04	0,028	0,028	0,028	0,027	0,026	0,025	0,280	0,280	0,275	0,270	0,267	0,265
0,06	0,031	0,031	0,030	0,029	0,028	0,027	0,290	0,287	0,284	0,280	0,277	0,275
0,08	0,034	0,034	0,033	0,032	0,031	0,030	0,303	0,300	0,295	0,290	0,287	0,283
0,10	0,037	0,036	0,036	0,034	0,033	0,032	0,312	0,309	0,305	0,300	0,297	0,292
0,20	0,046	0,046	0,045	0,043	0,043	0,041	0,352	0,349	0,343	0,337	0,330	0,325
0,40	0,060	0,058	0,057	0,055	0,054	0,053	0,405	0,402	0,393	0,383	0,378	0,375
0,60	0,068	0,067	0,065	0,064	0,063	0,061	0,435	0,432	0,426	0,417	0,412	0,407
0,80	0,073	0,072	0,071	0,069	0,068	0,067	0,455	0,452	0,446	0,440	0,436	0,432
1,00	0,077	0,076	0,074	0,073	0,071	0,070	0,470	0,467	0,461	0,455	0,450	0,445

TABLE D 46.1 (c) (see continuation)

(c) 3 GIRDERS 2 TRANSVERSES

GIRDERS												
$\beta$	B.M. COEFF. $K_1$						S.F. COEFF. $K_2$					
	$\alpha$						$\alpha$					
	0,0	0,2	0,4	0,6	0,8	1,0	0,0	0,2	0,4	0,6	0,8	1,0
0,02	0,240	0,230	0,220	0,195	0,135	0,0	1,000	1,000	1,000	1,000	1,000	1,000
0,04	0,240	0,230	0,220	0,195	0,135	0,0	1,000	1,000	1,000	1,000	1,000	1,000
0,06	0,240	0,230	0,220	0,195	0,135	0,0	1,000	1,000	1,000	1,000	1,000	1,000
0,08	0,240	0,230	0,220	0,195	0,135	0,0	1,000	1,000	1,000	1,000	1,000	1,000
0,10	0,240	0,230	0,220	0,195	0,135	0,0	1,000	1,000	1,000	1,000	1,000	1,000
0,20	0,235	0,227	0,219	0,195	0,135	0,0	1,000	1,000	1,000	1,000	1,000	1,000
0,40	0,215	0,215	0,200	0,189	0,135	0,0	0,960	0,980	1,000	1,000	1,000	1,000
0,60	0,195	0,195	0,195	0,180	0,135	0,0	0,870	0,900	0,950	1,000	1,000	1,000
0,80	0,175	0,175	0,175	0,170	0,135	0,0	0,790	0,840	0,890	1,000	1,000	1,000
1,00	0,165	0,165	0,165	0,160	0,125	0,0	0,720	0,770	0,840	0,960	1,000	1,000

TRANSVERSES												
$\beta$	B.M. COEFF. $K_1$						S.F. COEFF. $K_2$					
	$\alpha$						$\alpha$					
	0,0	0,2	0,4	0,6	0,8	1,0	0,0	0,2	0,4	0,6	0,8	1,0
0,02	0,007	0,006	0,006	0,005	0,005	0,005	0,147	0,145	0,140	0,137	0,137	0,125
0,04	0,009	0,007	0,007	0,006	0,005	0,005	0,147	0,145	0,140	0,137	0,137	0,125
0,06	0,010	0,008	0,008	0,007	0,006	0,005	0,155	0,152	0,142	0,137	0,137	0,125
0,08	0,011	0,009	0,009	0,008	0,007	0,005	0,163	0,157	0,150	0,140	0,137	0,125
0,10	0,013	0,011	0,011	0,009	0,007	0,005	0,167	0,165	0,155	0,145	0,137	0,125
0,20	0,018	0,015	0,015	0,012	0,008	0,005	0,195	0,186	0,180	0,162	0,144	0,125
0,40	0,026	0,023	0,021	0,017	0,010	0,005	0,235	0,220	0,210	0,185	0,152	0,125
0,60	0,032	0,029	0,025	0,020	0,011	0,005	0,262	0,247	0,232	0,202	0,160	0,125
0,80	0,037	0,033	0,029	0,022	0,013	0,005	0,285	0,270	0,250	0,217	0,165	0,125
1,00	0,041	0,038	0,033	0,025	0,014	0,005	0,302	0,287	0,267	0,230	0,170	0,125

Table D 46.1 (c)



TABLE D 46.1 (c) (continued)

(c) 3 GIRDERS 3 TRANSVERSES

GIRDERS												
$\beta$	B.M. COEFF. $K_1$						S.F. COEFF. $K_2$					
	$\alpha$						$\alpha$					
	0,0	0,2	0,4	0,6	0,8	1,0	0,0	0,2	0,4	0,6	0,8	1,0
0,02	0,335	0,325	0,300	0,265	0,210	0,140	1,620	1,620	1,620	1,620	1,620	1,620
0,04	0,335	0,325	0,300	0,265	0,210	0,140	1,620	1,620	1,620	1,620	1,620	1,620
0,06	0,335	0,325	0,300	0,265	0,210	0,140	1,620	1,620	1,620	1,620	1,620	1,620
0,08	0,335	0,325	0,300	0,265	0,210	0,140	1,620	1,620	1,620	1,620	1,620	1,620
0,10	0,335	0,325	0,300	0,265	0,210	0,140	1,620	1,620	1,620	1,620	1,620	1,620
0,20	0,325	0,310	0,290	0,260	0,210	0,140	1,540	1,620	1,620	1,620	1,620	1,620
0,40	0,285	0,275	0,265	0,240	0,200	0,125	1,370	1,420	1,460	1,500	1,500	1,500
0,60	0,255	0,250	0,245	0,225	0,185	0,115	1,240	1,300	1,360	1,440	1,450	1,450
0,80	0,225	0,225	0,220	0,210	0,180	0,105	1,120	1,200	1,280	1,360	1,420	1,420
1,00	0,205	0,205	0,205	0,200	0,170	0,095	1,040	1,120	1,200	1,300	1,400	1,400

TRANSVERSES												
$\beta$	B.M. COEFF. $K_1$						S.F. COEFF. $K_2$					
	$\alpha$						$\alpha$					
	0,0	0,2	0,4	0,6	0,8	1,0	0,0	0,2	0,4	0,6	0,8	1,0
0,02	0,009	0,008	0,007	0,006	0,005	0,004	0,150	0,145	0,140	0,135	0,130	0,125
0,04	0,011	0,010	0,009	0,008	0,007	0,006	0,162	0,157	0,153	0,148	0,143	0,138
0,06	0,013	0,012	0,011	0,010	0,009	0,008	0,175	0,170	0,163	0,158	0,150	0,147
0,08	0,015	0,014	0,013	0,012	0,011	0,010	0,185	0,180	0,170	0,165	0,157	0,155
0,10	0,017	0,016	0,015	0,014	0,013	0,011	0,192	0,187	0,180	0,175	0,165	0,160
0,20	0,025	0,024	0,023	0,021	0,018	0,017	0,230	0,225	0,220	0,210	0,195	0,185
0,40	0,036	0,035	0,034	0,031	0,027	0,024	0,285	0,275	0,270	0,257	0,237	0,220
0,60	0,045	0,044	0,043	0,038	0,033	0,029	0,325	0,315	0,305	0,290	0,267	0,247
0,80	0,051	0,050	0,048	0,043	0,038	0,033	0,355	0,345	0,330	0,317	0,290	0,270
1,00	0,056	0,055	0,052	0,047	0,043	0,036	0,380	0,370	0,355	0,340	0,310	0,287

## Section 47

## SIDE STRINGERS

## Symbols

4701

$S$  = span from span point to span point or from span point to side transverse, in metres, (minimum value to be taken as 3 m),

$b$  = width of plating supported, in metres. Where applicable, the width supported is to be taken as half the distance from the next stringer to the deck at side or base line as appropriate,

$h$  = head from stringer to highest point of tank, excluding hatchway, in metres.

## General

4702 Where transverse side framing is adopted, side stringers are to be fitted as required by D 4503.

## Scantlings

4703 The modulus of side stringers is not to be less than given by Table D 47.1:—

TABLE D 47.1

POSITION OF STRINGER	SECTION MODULUS cm <sup>3</sup>
Single	13,55 $b h S^2$
Upper of two or more	17,25 $b h S^2$
Middle or lower	13,55 $b h S^2$

4704 The depth of the stringer is not to be less than 2,5 times the depth of the slot for the frame.

4705 Where side transverses are not fitted the lower side stringers are to be supported by suitable buttress brackets from the bottom transverses.

4706 For minimum thicknesses, *see* D 4018.

For geometric properties of sections, *see* D 128.

## Section 48

## BOTTOM AND DECK GIRDERS

## Symbols

4801

$L$  = length of ship, in metres,

$D$  = moulded depth, in metres,

$S_G$  = span of girders, in metres, *see* Fig. D 48.1,

$s$  = spacing of transverses, in metres,

$b_t$  = breadth of tank, measured between faces of the vertical transverses where applicable, in metres,

$n$  = number of continuous longitudinal girders in tank breadth,

$m$  = number of transverses between support bulkheads.

## General

4802 The scantling requirements for the bottom girders are given for three basic girder support arrangements (*see* D 4602). Where an arrangement of bottom transverses and girders other than those detailed is proposed this will be specially considered.

## Bottom Girders

4803 The section modulus of the girder is not to be less than:—

$$\frac{I}{y} = \frac{62 K_1 b_t S_G D s}{(n + 1)} \text{ cm}^3$$

where  $K_1$  = coefficient derived from Table D 46.1. Minimum value of  $S_G = s (m - 0,8)$  metres.

For intercostal centreline docking girder, *see* 4805.

4804 The thickness of the girder web is to be such that the net sectional area of the web at any section in its length is not to be less than:—

$$A = \frac{Q_x}{F} \text{ cm}^2$$

where  $A$  = net sectional area of the web, including bracket where applicable, in cm<sup>2</sup>,

$Q_x$  = shear force at the actual section under consideration obtained from diagram constructed in accordance with Fig. D 48.1, in kN (tonne-f),

$F = 8,34 (0,85)$ ,

$$Q_1 = \frac{10,05 K_2 D s b_t}{(n + 1)} \text{ kN}$$



$$\left( Q_1 = \frac{1,025 K_2 D s b_t}{(n+1)} \text{ tonne-f} \right)$$

$$Q_2 = Q_1 \left( 1 - \frac{2}{m} \right)$$

where  $K_2$  = coefficient derived from Table D 46.1,

$b_e$  = effective bracket size, in metres (see D 130).

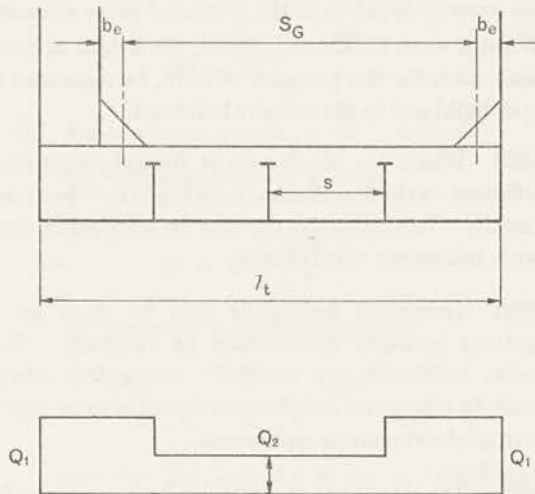


FIG. D 48.1

#### Intercostal Bottom Centreline Girder

4805 The section modulus of the girder is not to be less than:—

$$\frac{I}{y} = 3,6 b_t D s^2 \text{ cm}^3$$

The scantlings of the docking girder may require to be increased depending upon docking condition and support arrangements, details of which are to be submitted.

4806 The depth of an intercostal girder is not to exceed the depth of the transverses.

#### Continuous or Intercostal Bottom Centreline Girders

4807 Vertical webs are generally to be arranged on the transverse bulkheads in association with bottom centreline girders.

4808 For web stiffening, see D 51.

#### Continuous Deck Girders

4809 Where a continuous deck centreline girder is fitted, the section modulus is to be not less than:—

$$\frac{I}{y} = \frac{S_G^2 b_t L}{21} \text{ cm}^3$$

Where continuous side girders are fitted, the section modulus of these and the centreline girder is to be obtained by multiplying the above formula by  $\frac{1}{(n+1)}$

4810 Where intercostal side girders, having scantlings as required by 4811, are fitted in the centre tank the section modulus of the deck centre girder derived in accordance with 4809 may be reduced by 5 per cent.

#### Intercostal Deck Side Girders

4811 Intercostal side girders are to have a depth not less than 50 per cent of the depth of the deck transverse. The face area is not to be less than that of the transverses.

#### General

4812 For reduction to modulus of deck centre girder and deck transverses when side girders are fitted, see 4810 and D 4613.

4813 For minimum thicknesses, see D 4018.

For geometric properties of sections, see D 128.

### Section 49

#### CROSS TIES

4901 Cross ties may be of plate or sectional material and are to have an area,  $A$ , and least moment of inertia,  $I$ , not less than:—

$$A = k (64 + 1,035 / hs) \text{ cm}^2,$$

$$I = 2,45 l h s S^2 \text{ cm}^4,$$

where  $k$  = higher tensile steel factor, see D 116,

$l$  = one-half the distance, in metres, between the centre of the adjacent cross ties or between the centre of the adjacent cross tie and the centre of the bottom or deck transverse,

$h$  = vertical distance, in metres, from the centre of the cross tie to deck at side amidships,

$s$  = spacing of transverses, in metres,

$S$  = length of cross tie, in metres, between the toes of the horizontal tripping brackets on the transverse webs at the cross ties. Special consideration will be given where alternative arrangements omitting the tripping brackets are provided.

Diagonal cross ties will be specially considered but, in general, the area and least moment of inertia of the horizontal cross tie is not to be less than 85 per cent of that required by the above formula assuming the centre cross tie only is fitted. The area of each diagonal cross tie is not to be less than 85 per cent of that required for the horizontal cross tie.

**4902** Cross ties are to be connected to the vertical transverses or horizontal girders by suitable brackets. Tripping brackets are to be fitted to the transverses in way of the cross ties and where scallops for longitudinals or frames come in way of the cross ties they are to be closed by plate collars.

**4903** Cross ties are to be provided with suitable horizontal stiffening to prevent buckling and twisting. Where the unsupported width of face plate exceeds 150 mm, additional vertical stiffening is to be arranged to support the face plate.

## Section 50

### OILTIGHT AND NON-OILTIGHT BULKHEADS

#### Symbols

5001

- $L$  = length of ship, in metres,
- $D$  = moulded depth, in metres, to deck at side amidships,
- $b$  = width of plating supported, in metres, or as stated otherwise,
- $h$  = distance, in metres, from a point one-third of the height of the plate above its lower edge to highest point of tank, excluding the hatchway,
- $h_1$  = distance, in metres, from centre of span to highest point of tank, excluding the hatchway,
- $k$  = higher tensile steel factor, *see* D 116,
- $S$  = span of stiffener, corrugation, web or girder, in metres, measured between girders, girder to span point or span point to span point as appropriate. For horizontal girders on longitudinal bulkheads a minimum value of 3 m is to be used,
- $s$  = spacing of stiffeners, in mm, or the breadth, in mm, of flange or web, whichever is the greater, of corrugated bulkheads (i.e. "b" or "c" in Fig. D 1.2).

### OILTIGHT BULKHEADS

#### General

**5002** Longitudinal bulkheads, other than at the centreline, are to be oiltight throughout the cargo tanks and may be plane or horizontally corrugated.

Longitudinal bulkheads may be perforated in pump-rooms, cofferdams, stabilizer tanks and in other compartments (where these are clear of the cargo tanks), provided suitable account is taken of the increased shear stresses.

When a wash bulkhead is fitted, the length or breadth of a tank may, for the purposes of 5016, be measured from the wash bulkhead to the oiltight bulkhead.

**5003** Where the ship's side is framed longitudinally the stiffening on the longitudinal bulkheads is to be arranged horizontally. Vertical stiffening may be adopted in association with transverse side framing.

**5004** Transverse bulkheads may be plane or with corrugations arranged horizontally or vertically. Where transverse bulkheads are vertically corrugated, adequate resistance to transverse compressive forces is to be provided by horizontal stringers or equivalent.

**5005** The scantlings of cofferdam bulkheads not forming the boundary of a cargo tank are to be as required by D 19 for oil fuel deep tanks.

Where the pump room is acting as a cofferdam, a bulkhead which does not form part of the boundary of a cargo tank or an oil fuel bunker may be of watertight bulkhead scantlings in accordance with D 18, provided that an inert gas system is fitted and the notation "IGS" assigned to the ship. *See also* B 107.

**5006** Longitudinal bulkheads are to extend as far forward and aft as is practicable and are to be effectively scarfed to the adjoining structure.

#### Higher Tensile Steel

**5007** Where higher tensile steel is used, the section modulus of the stiffeners is to be multiplied by the factor  $k$  and the plating thickness by the factor  $\sqrt{k}$ . Corrugated bulkheads may be similarly treated except that the minimum moment of inertia shall not be reduced.

### PLANE BULKHEADS

#### Plating—Transverse Bulkheads

**5008** The thickness of the plating is to be not less than:—

$$t = 0,004 s \sqrt{h} + 2,5 \text{ mm}$$



and is in no case to be less than:—

- (a) For the upper three-quarters of the bulkhead:—  
for vertically stiffened panels:

$$t = \frac{a}{70 + 30 \left(\frac{a}{b}\right)^2} \text{ mm}$$

for horizontally stiffened panels:

$$t = \frac{a}{80 + 20 \frac{a}{b}} \text{ mm}$$

- (b) For the lower quarter of the bulkhead:—  
for vertically stiffened panels:

$$t = \frac{a}{58 + 27 \left(\frac{a}{b}\right)^2} \text{ mm}$$

for horizontally stiffened panels:

$$t = \frac{a}{65 + 20 \frac{a}{b}} \text{ mm}$$

where  $a$  = the least dimension of unstiffened plate panel, in mm,

$b$  = the greatest dimension of unstiffened plate panel, in mm.

#### Plating—Longitudinal Bulkheads

5009 The thickness of plating is not to be less than that given in 5008 except that:—

- (a) Within 0,1D of the bottom shell the thickness of plating is not to be less than:

$$t = 0,004\,25\,s\sqrt{h} + 2,5 \text{ mm}$$

and is in no case to be less than  $\frac{s}{55}$  with horizontal stiffening or  $\frac{s}{40}$  with vertical stiffening.

- (b) Within 0,1D of the deck the thickness of plating is not to be less than the thickness from (a) above less 1,5 mm, and is in no case to be less than  $\frac{s}{55}$  with horizontal stiffening or  $\frac{s}{40}$  with vertical stiffening.

For minimum thickness, see D 4018.

#### Stiffeners

5010 The section modulus of horizontal or vertical stiffeners, other than horizontal stiffeners on longitudinal

bulkheads, is not to be less than:—

$$\frac{I}{y} = \frac{s S^2}{117,5} (h_1 + 0,9) \text{ cm}^3$$

The section modulus given by this formula is that of the stiffeners and associated plating, see D 126.

5011 The modulus of horizontal stiffeners on longitudinal bulkheads is not to be less than:—

$$\frac{I}{y} = 0,013\,55\,sS^2 K_1 \text{ cm}^3$$

where  $K_1$  is as defined for side shell stiffeners in D 4402 and Table D 44.1.

These longitudinals are to comply with the requirements of D 4404.

5012 The modulus of vertical stiffeners on longitudinal or transverse bulkheads may be reduced by 10 per cent where vertical webs are fitted.

5013 Stiffeners are to be bracketed or otherwise efficiently connected at their ends to provide adequate fixity and, for horizontal stiffeners, continuity of longitudinal strength at the bulkheads.

The end brackets of longitudinal bulkhead vertical stiffeners are to be as required by Table D 32.3 and are to be connected to a suitable longitudinal or are to be well hollowed and tapered.

All stiffeners are to be connected to the supporting webs or girders as required by Table D 32.4.

The plating is to be efficiently stiffened to support loads transmitted by end connections of longitudinal bulkhead, shell and deck longitudinals and the like.

#### Webs and Girders

5014 The section modulus of vertical webs and horizontal girders is not to be less than that required by Table D 50.1.

For intercostal vertical webs not supporting stiffeners (item 2 in Table D 50.1)  $b_1$  is to be taken as half the breadth of centre tank (or the breadth of wing tank) divided by the number of webs plus one (number of webs to be those in the half-breadth of centre tank or breadth of wing tank as appropriate) and  $S$  is to be measured between girders or from girder to span point. The maximum value of  $6,9\,b_1\,h_1\,S^2$  is to be used for the full depth of bulkhead.

5015 Where the distance between transverse bulkheads (whether oiltight or non-oiltight) exceeds 24,5 m, and continuous side girders are not fitted in the centre tank, the centreline vertical web is to be symmetrical on both sides of the transverse bulkhead.

TABLE D 50.1

ITEM	SECTION MODULUS cm <sup>3</sup>
1. VERTICAL WEBS (other than in (2) below)	
(a) On transverse bulkheads not forming a ring system* (other than including the web on the centreline).	12,65b h <sub>1</sub> S <sup>2</sup>
(b) On transverse bulkheads forming a ring system* (other than at centreline) as primary supporting members and supporting horizontal stiffeners.	10b h <sub>1</sub> S <sup>2</sup>
(c) On longitudinal bulkheads	as for side transverse
2. INTERCOSTAL VERTICAL WEBS ON TRANSVERSE BULKHEADS NOT SUPPORTING STIFFENERS	6,9b <sub>1</sub> h <sub>1</sub> S <sup>2</sup>
3. HORIZONTAL GIRDERS ON LONGITUDINAL OR TRANSVERSE BULKHEADS	
(a) Single girder	11,9b h <sub>1</sub> S <sup>2</sup>
(b) Upper of two or more	14,6b h <sub>1</sub> S <sup>2</sup>
(c) Middle or lower	11,9b h <sub>1</sub> S <sup>2</sup>

\* i.e. in association with bottom and deck girders of Rule scantlings.

(See also 5015 to 5017)

**5016** Where webs are symmetrical on each side of a plane bulkhead the section modulus derived as above may be reduced by 10 per cent.

**5017** Where the breadth of a cargo tank exceeds 14 m, the section modulus of the horizontal girders on the longitudinal bulkhead is to be increased at the rate of 2 per cent per 0,3 m excess above 14 m.

**5018** Where side transverses are required by D 4504, vertical webs are to be fitted on the longitudinal bulkhead. Where vertical webs are not fitted, the lower horizontal girders are to be supported by suitable buttress brackets from the bottom transverses.

**5019** The depth of a girder or web is not to be less than 2,5 times the depth of the slot for the stiffener.

For minimum thicknesses, see D 4018.

For moduli of webs and girders of various depths, face areas and bulkhead plating, see D 128.

**5020** The end attachments of vertical webs and horizontal girders are to have a length of arm at least equal to the depth of web.

## CORRUGATED BULKHEADS

## General

**5021** Where corrugated bulkheads are adopted the corrugations should be arranged in accordance with 5002 and 5004.

**5022** In ships above 180 m in length the upper and lower strakes of the longitudinal bulkhead are to be plane for a distance of 0,1D from the deck and bottom and the vertical webs are to be arranged symmetrically on each side of the longitudinal bulkhead. Alternative arrangements with asymmetrical webs will be specially considered, having in view the spacing of transverses and the type of transverse bulkhead, etc.

## Plating

**5023** The thickness of plating of transverse and longitudinal bulkheads is not to be less than that required by 5008 and 5009 respectively.

The thickness of plating is also to be such that the requirements of 5024 are satisfied.

For minimum thickness, see D 4018.

**5024** The minimum angle of corrugation is to be 40° and the dimensions of the corrugations are to fulfil the following conditions:—

$$\frac{d_w (3bt_p + ct_w)}{59 p} \text{ not to be less than } h_1 S_1^2 \quad (1)$$

$$\frac{d_w^2 (3bt_p + ct_w)}{3800p} \text{ not to be less than } h_1 S_1^3 \quad (2)$$

where  $S_1$  = span of corrugation, in metres, measured from girder to girder, transverse to transverse or side, bottom, deck or bulkhead to transverse or girder,

and  $t_p$ ,  $t_w$ ,  $b$ ,  $c$ ,  $d_w$  and  $p$ , in mm, are as given in D 127 and Fig. D 1.2.

**5025** Where the shear force has to be investigated the thickness of the longitudinal bulkhead plating may require to be increased.

**5026** Corrugations are to be in line, and of the same form, on each side of bulkheads, horizontal girders and vertical webs.

## Webs and Girders

**5027** Horizontal girders and vertical webs are to be arranged to support the corrugations. The spacing of



TABLE D 50.2

ITEM	SECTION MODULUS cm <sup>3</sup>
<b>1. VERTICAL WEBS</b>	
(a) ON VERTICALLY CORRUGATED BULKHEADS	
At centreline	$12,65b h_1 S^2$
Other webs forming a ring system* and not supporting girders	$6,9b_1 h_1 S^2$
(b) ON HORIZONTALLY CORRUGATED BULKHEADS	
(i) Transverse bulkheads:	
At centreline	$12,65b h_1 S^2$
Other webs forming a ring system*	$10b h_1 S^2$
Webs not forming a ring system	$12,65b h_1 S^2$
(ii) Longitudinal bulkheads	as for side transverse
<b>2. HORIZONTAL GIRDERS ON VERTICALLY CORRUGATED TRANSVERSE BULKHEADS</b>	
(a) Single girder	$11,9b h_1 S^2$
(b) Upper of two or more	$14,6b h_1 S^2$
(c) Middle or lower	$11,9b h_1 S^2$

\* i.e. in association with bottom and deck girders of Rule scantlings.

(See also 5029 and 5030)

transverses on longitudinal bulkheads is generally not to exceed 5 m.

**5028** The section modulus of vertical webs and horizontal girders is not to be less than that required by Table D 50.2.

For vertical webs forming a ring system and not supporting girders,  $b_1$  is to be taken as half the breadth of the centre tank (or breadth of wing tank) divided by the number of webs plus one, and  $S$  is to be measured between girders or from girder to span point. The maximum value of  $6,9b_1 h_1 S^2$  is to be used for the full depth of bulkhead.

**5029** Where the distance between transverse bulkheads (whether oiltight or non-oiltight) exceeds 25 m, and continuous side girders are not fitted in the centre tank, the centreline vertical web is to be symmetrical on both sides of the transverse bulkhead.

**5030** Where webs or girders are symmetrical on each side of a corrugated bulkhead, the section modulus derived as above may be reduced by 10 per cent.

**5031** For minimum thickness, see D 4018.

For geometric properties of sections, see D 128.

**5032** The end attachments of vertical webs and horizontal girders are to have a length of arm at least equal to the depth of web.

### NON-OILTIGHT BULKHEADS (PLANE OR CORRUGATED)

#### General

**5033** Wash bulkheads and perforated centreline longitudinal bulkheads are to have an area of perforations not less than 10 per cent of the total area of the bulkhead. The perforations are to be so arranged that the bulkheads act as an efficient girder, web or transverse and the lower part of a centreline bulkhead is to be adequately stiffened to act as a docking girder. See also 5040.

Where no continuous girders are fitted, consideration will be given to the omission of complete wash bulkheads provided that suitable deck transverses are arranged.

Special care is to be taken to ensure that a perforated centreline longitudinal bulkhead provides an efficient connection between the deck and bottom plating.

#### Plating

**5034** The thickness of plating may be the compartment minimum (see D 4018) except that the top and bottom strakes of a centreline bulkhead are to be as required by 5009 for an oiltight longitudinal bulkhead. See also 5040.

#### Higher Tensile Steel

**5035** Where higher tensile steel is used, the section modulus of the stiffeners is to be multiplied by the factor  $k$ , and the plating thickness by the factor  $\sqrt{k}$ , but the minimum thickness required by 5040 is not to be reduced.

#### Stiffeners, Girders and Webs

**5036** The section modulus of stiffeners and horizontal girders is to be not less than:—

$$\frac{I}{y} = k s_1 S^2 \frac{l}{L} \text{ cm}^3$$

where  $k = 1215 \times 10^{-4}$  for stiffeners on transverse bulkheads,

$= 3785 \times 10^{-4}$  for stiffeners on longitudinal bulkheads,

$= 145$  for girders on transverse bulkheads,

$= 452$  for girders on longitudinal bulkheads,

$S_1$  = spacing of stiffeners, in mm, or width of plating supported by girder, in metres,

$l$  = length or breadth, in metres, of tank between oiltight bulkheads for transverse or longitudinal bulkheads respectively. Where two or more transverse wash bulkheads are fitted in one tank,  $l$  is to be measured between the bulkheads adjacent to the wash bulkhead under consideration.

**5037** The section modulus of vertical webs is to be not less than:—

On transverse bulkheads—the modulus required for an oiltight bulkhead multiplied by  $\left(0,3 + 2 \frac{l}{L}\right)$  where  $l$  is as defined in 5036.

On longitudinal bulkheads—50 per cent of that required for an oiltight bulkhead.

**5038** The depth of webs and girders is to be at least 2,5 times the depth of the slot for the stiffener.

**5039** When determining the width of plating supported and the effective area for calculating the modulus no deduction is to be made on account of perforations.

**5040** Where non-oiltight transverse bulkheads support continuous fore and aft girders, the following additional requirements are to be met. The area of perforation is not to be greater than 25 per cent of the total area of the bulkhead, and consideration should be given to the disposition and geometry of the perforations such that the shear rigidity of the bulkhead is a maximum. The lower section of the bulkhead is to be devoid of non-essential openings for a depth equal to 1,75 times the depth of the longitudinal girders which it supports. Essential openings for pipes, access, etc., in the lower section should preferably be circular with edge stiffening or otherwise suitably framed.

The net sectional area of the bulkhead is not to be less than:—

$$A = \frac{n l_b b_t D}{1,85 (n + 1)} \text{ cm}^2$$

where  $l_b$  = half the distance between adjacent transverse support bulkheads forward and aft of the wash bulkhead under consideration, in metres,

$n$  = number of longitudinal continuous girders supported by bulkhead,

$b_t$  = breadth of tank, in metres.

The thickness of the plating is to be not less than:—

(a) For the upper three-quarters of the wash bulkhead:—

for vertically stiffened panels:

$$t = \frac{a}{70 + 30 \left(\frac{a}{b}\right)^2} \text{ mm}$$

for horizontally stiffened panels:

$$t = \frac{a}{80 + 20 \frac{a}{b}} \text{ mm}$$

(b) For the lower quarter of the wash bulkhead:—  
for vertically stiffened panels:

$$t = \frac{a}{58 + 27 \left(\frac{a}{b}\right)^2} \text{ mm}$$

for horizontally stiffened panels:

$$t = \frac{a}{65 + 20 \frac{a}{b}} \text{ mm}$$

where  $a$  = least dimension of unstiffened plate panel, in mm,

$b$  = greatest dimension of unstiffened plate panel, in mm, which should not exceed 180t or 180 times the thickness required by 5034, whichever is the greater.

## Section 51

### CONSTRUCTION DETAILS FOR PRIMARY SUPPORTING MEMBERS

#### Symbols

##### 5101

$L$  = length of ship, in metres,

$t$  = thickness, in mm, of the web of the member,

$d_w$  = depth, in mm, of the web of the member,

$s$  = spacing, in mm, of stiffeners on the web,

$s_1$  = depth of cross tie, in mm, or distance between horizontal stiffeners,

$S$  = span, in metres, of the web stiffener between effective support points,

$A_s$  = cross-sectional area, in  $\text{cm}^2$ , of the web stiffener and associated web plating,

$I_s$  = moment of inertia, in  $\text{cm}^4$ , of the web stiffener,

$t_b$  = thickness, in mm, of the end bracket,



- $d_b$  = arm length, in metres, of the end bracket,  
 $l_b$  = length, in metres, of the free edge of end bracket,  
 $A_b$  = cross-sectional area, in  $\text{cm}^2$ , of the end bracket edge stiffeners and associated plating (see Fig. D 51.2),  
 $I_b$  = moment of inertia, in  $\text{cm}^4$ , of the end bracket edge stiffeners and associated plating (see Fig. D 51.2).

**5102** Primary supporting members, that is, girders, transverses, webs and stringers are to be so arranged as to ensure effective continuity of strength throughout the range of tank structure. Abrupt changes of depth or section are to be avoided.

Where members abut on both sides of a bulkhead or on other members, arrangements are to be made to ensure that they are in alignment.

**5103** The members are to have adequate end fixity, lateral support and web stiffening, and the structure is to be arranged to minimize hard spots or other sources of stress concentration. Openings are to have well rounded corners and smooth edges and are to be located having regard to the stress distribution and buckling strength of the plate panel.

#### Direct Calculations

**5104** Where direct calculation methods are used to analyse the stress distribution in the primary structure, details of the assumptions made and the calculations are to be submitted for approval. These methods may include detailed analysis of the primary member construction by finite element or equivalent techniques.

Direct calculation methods may be required where considered necessary.

**5105** Where such analysis has been carried out, the construction details and stiffening of the primary members will be considered in relation to the results obtained and the subsequent requirements of this Section may be modified.

#### Web Plate Stiffening

**5106** The webs of primary supporting members are to be supported and stiffened in accordance with the following requirements, which are designated as Requirements "A", "B", "C", "D" and "E". The application of these Requirements is detailed in 5114 and the corresponding locations indicated in Fig. D 51.1.

All thicknesses used in these Requirements are to be thicknesses before reduction for corrosion control.

In addition to these stiffeners, tripping brackets as required by 5118 are also to be fitted.

#### Requirement "A" Stiffening

##### 5107

- (a) The thickness,  $t$ , of the web plating is to be not less than  $\frac{s}{80}$  or the compartment minimum thickness (see D 4018), whichever is the greater.
- (b) Stiffening normal to the face plate of the member is to be fitted, but stiffeners parallel to the face plate will be required when the web depth,  $d_w$ , exceeds a value  $d_{\max.}$ , which is to be taken as:—

$$\text{For } s \leq 55t \quad d_{\max.} = 3s$$

$$s > 55t \quad d_{\max.} = \frac{45st}{s - 40t}$$

- (c) Where parallel stiffening is required, the distance from the face plate of the member to the nearest parallel stiffener is not to exceed  $65t$ . Further stiffeners are to be fitted at similar spacing such that the distance between the last stiffener and the shell or bulkhead plating does not exceed  $d_{\max.}$ .

Where the web plate is slotted for the passage of stiffeners, these stiffeners are to be supported by web stiffeners normal to the attached plating. The length of these stiffeners is to be sufficient to provide adequate support for the load transmitted.

#### Requirement "B" Stiffening

##### 5108

- (a) The thickness,  $t$ , of the web plating is not to be less than  $\frac{s}{85}$  or the compartment minimum thickness (see D 4018), whichever is the greater.
- (b) Stiffening normal to the face plate of the member is to be fitted, but stiffeners parallel to the face plate will be required when the web depth,  $d_w$ , exceeds a value  $d_{\max.}$ , which is to be taken as:—

$$\text{For } s \leq 70t \quad d_{\max.} = 3s$$

$$s > 70t \quad d_{\max.} = \frac{48st}{s - 54t}$$

- (c) Where parallel stiffening is required, the distance from the face plate of the member to the nearest parallel stiffener is not to exceed  $80t$ . Further stiffeners are to be fitted at similar spacing such that the distance between the last stiffener and the shell or bulkhead plating does not exceed  $d_{\max.}$ .

Where the web plate is slotted for the passage of stiffeners, these stiffeners are to be supported by web

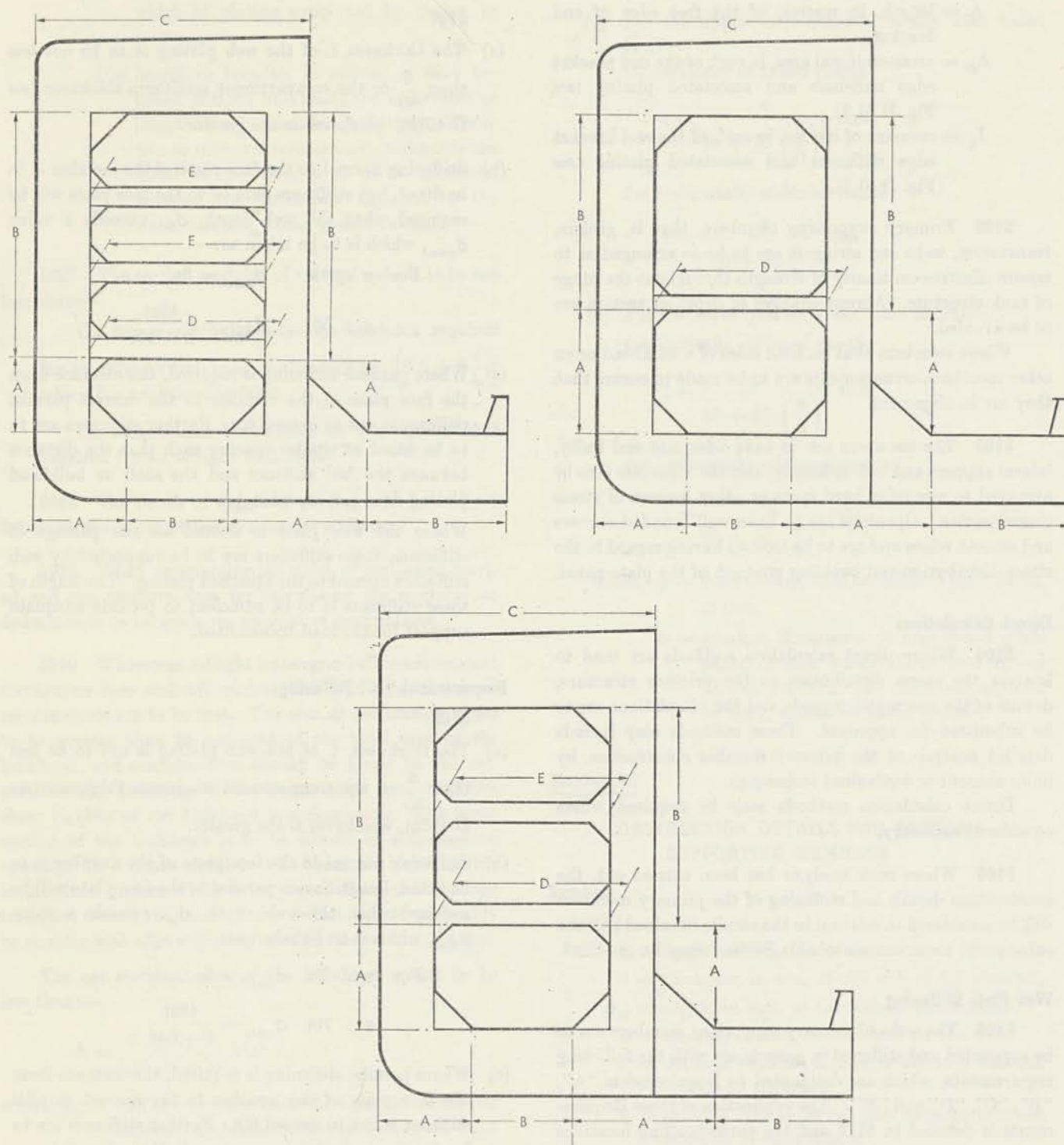


FIG. D 51.1 KEY TO APPLICATION OF STIFFENING REQUIREMENTS



stiffeners normal to the attached plating. The length of these stiffeners is to be sufficient to provide adequate support for the load transmitted.

#### Requirement "C" Stiffening

##### 5109

- (a) The thickness,  $t$ , of the web plating is not to be less than the compartment minimum (see D 4018).
- (b) Stiffening normal to the face plate of the member is to be fitted at alternate longitudinals, but stiffeners parallel to the face plate will be required when the web depth,  $d_w$ , exceeds a value  $d_{max.}$ , which is to be taken as:—

$$\text{For } s \leq 76t \quad d_{max.} = 3s$$

$$s > 76t \quad d_{max.} = \frac{48st}{s - 60t}$$

- (c) Where parallel stiffening is required, the distance from the face plate of the member to the nearest parallel stiffener is not to exceed  $90t$ . Further stiffeners are to be fitted at similar spacing such that the distance between the last stiffener and the deck plating does not exceed  $d_{max.}$ .

#### Requirement "D" Stiffening

##### 5110

- (a) The thickness,  $t$ , of the web plating is not to be less than  $\frac{S_1}{80}$  for  $L = 90$  metres, and  $\frac{S_1}{55}$  for  $L \geq 190$  metres, nor less than the compartment minimum. Intermediate values are to be obtained by interpolation.
- (b) Where parallel stiffening is required, the distance from face plate of the cross tie to nearest parallel stiffener is not to exceed the values given in (a).
- (c) Vertical brackets are to be fitted to support face plate and parallel stiffeners.

#### Requirement "E" Stiffening

##### 5111

- (a) The thickness,  $t$ , of the web plating is not to be less than  $\frac{S_1}{85}$  for  $L = 90$  metres, and  $\frac{S_1}{60}$  for  $L \geq 190$  metres, nor less than the compartment minimum. Intermediate values are to be obtained by interpolation.
- (b) Where parallel stiffening is required, the distance from face plate of the cross tie to nearest parallel stiffener is not to exceed the values given in (a).
- (c) Vertical brackets are to be fitted to support face plate and parallel stiffeners.

#### Moment of Inertia of Web Stiffeners

5112 The minimum moment of inertia of web stiffeners required by Requirements "A", "B", "C", "D" or "E" is to be taken as:—

- (a) Stiffeners normal to the primary member face plate: the moment of inertia,  $I_s$ , of the stiffener is not to be less than  $p s t^3 \times 10^{-4} \text{ cm}^4$ , where  $p$  is to be obtained from Table D 51.1 and  $t$  need not be taken greater than:

$$\frac{s}{55} \text{ for panels subject to Requirement "A"}$$

$$\frac{s}{70} \text{ for panels subject to Requirement "B" or "C".}$$

For values of  $t$  for panels subject to Requirement "D" or "E", see 5110 and 5111.

- (b) Stiffeners parallel to the primary member face plate: the moment of inertia,  $I_s$ , of the stiffener is not to be less than:

- (i) on transverses, webs and stringers

$$I_s = 2S^2 A_s \text{ cm}^4$$

- (ii) on longitudinal deck and bottom girders

$$I_s = 2,85S^2 A_s \text{ cm}^4$$

- (c) If both normal and parallel stiffeners are fitted, the inertia of the parallel stiffeners is not to be less than that of the stiffeners normal to the face plate of the member.

#### Depth and Proportion of Stiffeners

5113 The minimum depth of web stiffeners is to be 75 mm.

Where flat bar stiffeners are used, the depth to thickness ratio of the stiffener is not to exceed 18 to 1.

#### Application of Stiffening Requirements

5114 The Requirements as detailed above are to be applied in the following locations. See also Fig. D 51.1.

- (a) Bottom Transverses.

In the centre tank, Requirement "A" stiffening is to extend for 20 per cent of the breadth of the tank from the longitudinal bulkhead, but at least as far as the toe of the end bracket.

In the wing tank, Requirement "A" stiffening is to extend at least as far as the toes of the end brackets from the longitudinal bulkhead and the shell.

Elsewhere, Requirement "B" stiffening is to be fitted.



TABLE D 51.1

ASPECT RATIO OF PLATE PANEL	1,0 OR MORE	0,9	0,8	0,7	0,6	0,5	0,4	0,3 OR LESS
p	1,5	2,1	2,9	4,2	6,1	9,2	14,6	30,0

Intermediate values are to be obtained by interpolation.

(b) Transverses at Shell and Longitudinal Bulkhead.

Requirement "A" stiffening is to extend to at least as far as the lower surface of the lowest cross tie. Elsewhere, Requirement "B" stiffening is to be fitted. Where no cross tie is fitted, the stiffening requirements are to be specially considered on the basis of direct calculations.

(c) Deck Transverses.

Requirement "C" stiffening is to be fitted.

(d) Stringers and Horizontal Girders.

Requirement "A" stiffening is to extend for a distance from each end of 20 per cent of the span of the stringer or girder, but at least as far as the toes of the end brackets.

Elsewhere, Requirement "B" stiffening is to be fitted.

(e) Cross Ties.

Requirement "D" stiffening is to be fitted to the lowest or to a single cross tie.

Requirement "E" stiffening is to be fitted to the upper cross ties where two or more cross ties are arranged.

#### Stiffening of Continuous Longitudinal Girders

**5115** The webs of continuous longitudinal deck and bottom girders are to be stiffened parallel to the girder face plate.

The stiffeners are to be spaced not more than 55t mm apart except in way of vertical webs and end brackets where the spacing is not to exceed 45t mm. Alternatively a combination of parallel stiffeners at 55t mm spacing and normal stiffeners at 45t mm spacing may be adopted. Particular attention is to be given to the stiffening for the docking girder. See 5117.

The moment of inertia of the stiffeners is to comply with 5112.

#### Stiffening of Vertical Webs on Transverse Bulkheads

**5116** Vertical webs are to be fitted with stiffeners parallel to the face plate of the web and spaced not more

than 60t mm apart. Stiffeners normal to the face plate are to be fitted when a vertical web supports horizontal stiffeners on transverse bulkheads. The length of stiffener is to be sufficient to distribute the load transmitted.

The moment of inertia of the stiffeners is to comply with 5112.

#### Docking Brackets on Bottom Centreline Girder

**5117** Stiffened docking brackets are to be fitted on both sides of the bottom centreline girder, midway between transverses, and are to be connected to a suitable bottom shell longitudinal. The bracket on one side is to be connected to the face plate of the girder but the other may be stopped at a suitable horizontal stiffener.

Additional vertical stiffeners may be required on the bottom panels of the girder to resist docking pressures.

#### Lateral Stability

**5118** Tripping brackets are generally to be fitted close to the toes of end brackets in way of cross ties and elsewhere such that the spacing between brackets does not exceed the lesser of 4,5 metres or 15b metres (20b metres for deck transverses), where b is the width, in metres, of the face plate. Arrangements in way of the intersections of primary members are to be such as to prevent tripping.

Substantial brackets, to maintain continuity of strength, are to be fitted to transverses or stringers at ends of cross ties. These brackets are to be aligned with the cross tie face plate.

**5119** Tripping brackets are to be connected to the face plate of the bottom transverses. Elsewhere, the bracket is to be connected to the face plate whenever the unsupported width of the latter exceeds 150 mm. Where the width of symmetrically placed face plates exceeds 400 mm, a small bracket is to be fitted opposite, and in line with, the tripping bracket.

Wide face plates may require additional support between brackets.



**Openings in Web Plating**

**5120** Where openings are cut in the webs of primary supporting members, the greatest dimension of the opening is not to exceed 20 per cent of the web depth. The opening is to be located such that the edges are not less than 40 per cent of the web depth from the face, and are equidistant from the corners of notches for frames or stiffeners. Openings are to be suitably framed where required.

**5121** Lightening holes are not to be cut in horizontal girders on the ship's side and longitudinal bulkheads, in symmetrical webs nor in side transverses and vertical webs in way of cross ties and their end connections.

Holes cut in primary longitudinal members within 0,1D of the upper deck are, in general, to comply with the requirements of D 4211 and D 4212. Access holes may be cut in deep transverses and girders with suitable compensation if necessary.

All holes are to have smooth edges and are to be kept well clear of notches and the toes of brackets.

**5122** Small air and drain holes cut in primary members are to be kept clear of the toes of brackets and are to be well rounded with smooth edges. Where holes are cut in primary longitudinal members of higher tensile steel, they are to be elliptical or equivalent to minimize stress concentrations.

**5123** Where holes are cut for heating coils, the lower edge of the hole is not to be less than 100 mm from the inside of the shell plating.

Where large notches are cut in the transverses for the passage of longitudinal framing, the location of openings for heating coils will be considered. Examination of the buckling strength of the web plate panel between notches may be required.

**Notches**

**5124** Notches cut for the passage of longitudinals or stiffeners are to be designed to minimize the creation of stress concentrations. Corner radii are to be as large as practicable with a minimum of 20 per cent of the breadth of the notch, or 25 mm, whichever is the greater. The edges are to be smooth. It is recommended that web plate connection to the shell or bulkhead should end in a smooth tapered "soft toe" at the base of the notch.

Collars or equivalent reinforcement are to be fitted to notches in areas of high stress, such as at the toes of brackets and in way of the ends of cross ties.

**5125** Consideration is to be given to the load to be conveyed from the stiffener into the primary member at the notch, and additional lug connections or partial or complete collars may be required.

The critical shear buckling stress of the plate panel in which the notch is located is also to be investigated and reinforcement may be required.

**Brackets Connecting Primary Supporting Members**

**5126** The arm length of brackets connecting primary supporting members should not, in general, be less than the depth of the member web nor exceed 1,5 times the web depth. The two arms should be of approximately equal lengths.

**5127** In a ring system where the end bracket is integral with the webs of the members, and the face plate is carried continuously along the edges of the members and the bracket, the full area of the largest face plate is to be maintained to the mid-point of the bracket and gradually tapered to the smaller face plate. Butts in face plates are to be kept well clear of the toes of brackets. Where a wide face plate abuts on a narrower one the taper is generally not to exceed 1 in 4. Where a thick face plate abuts against a thinner one, if the difference in thickness exceeds 3 mm the taper on thickness is not to exceed 1 in 3.

**5128** The thickness of separate end brackets is generally not to be less than that of the thicker of the primary member webs being connected, but may require to be increased locally at the toes. The bracket is to extend to adjacent tripping brackets, stiffeners or other support points. Bracket toes are to be well radiused. Where the bracket is attached to a corrugated bulkhead, suitable arrangements are to be made to dissipate the load at the bracket toe. Welding in way of toes of separate brackets will be specially considered, with a requirement for full penetration welding.

**5129** Brackets are to be fitted with suitable face plates and stiffeners. The maximum distance of the first stiffener lying parallel to the face plate from the face is to be  $30t_b$ . Subsequent stiffeners lying parallel to the face may be spaced not more than  $45t_b$  apart. The maximum arm length for an unstiffened triangular panel is  $100t_b$  (see Fig. D 51.2). The depth of stiffeners is to be not less than 75 mm and their moment of inertia is to comply with 5112 (b).

**5130** The area of discontinuous face plates is generally to be about 80 per cent of the area of the face plates of the adjacent members. However where the stiffener adjacent to the face plate is of increased size then consideration will be given to the face area required. In addition the following expression is to be satisfied:—

$$\sqrt{\frac{I_b}{A_b}} \geq 2l_b \quad (\text{see Fig. D 51.2})$$



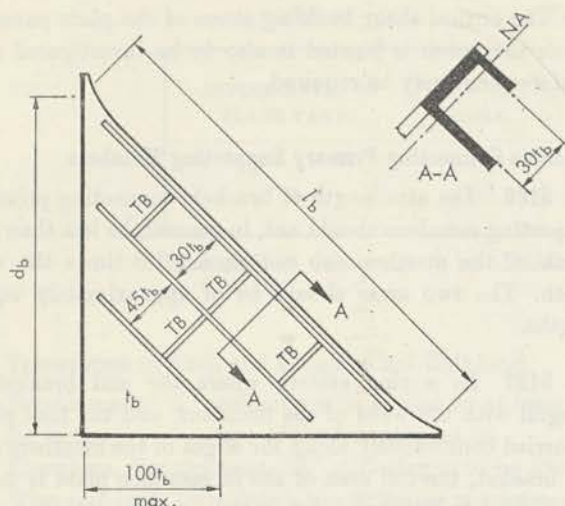


FIG. D 51.2

**5131** The ends of discontinuous face plates are to be well tapered. The taper may be 1 in 3, but where the width of the face plate exceeds 500 mm, a taper not less than 1 in 4 is generally to be adopted. Stiffeners adjacent to the face plate should be tapered 1 in 2 and other stiffeners may be cut at 45°.

**5132** Face plates and stiffeners are to be suitably supported against tripping (see Fig. D 51.2).

**5133** In the case of very large brackets with heavy face plates, it is recommended that special tripping brackets be fitted in line with the main member tripping brackets to provide lateral stability to the face plate (see Fig. D 51.3).

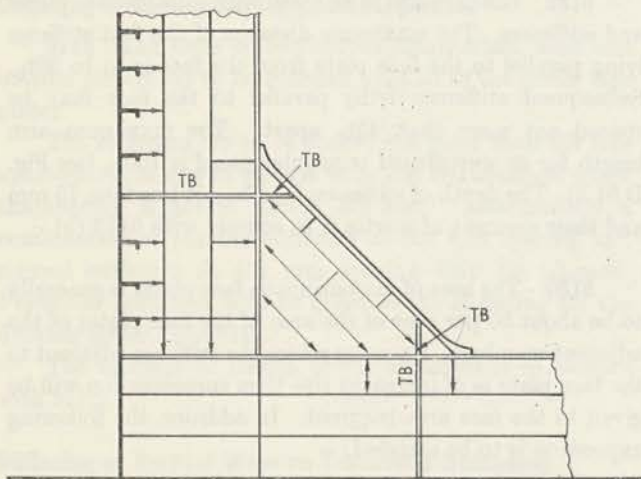


FIG. D 51.3

### Cross-references

**5134** For details of welding and welded connections, see D 32.

### Section 52

#### TESTING

##### General

**5201** Each cargo tank and cofferdam is to be separately tested by filling with water to the test head.

When water testing on the building berth or in drydock may be undesirable, testing may be carried out afloat, provided any riveted shell seams in the bottom and bilge plating are tested with a high pressure hose test on the berth. The testing afloat is to be carried out by separately filling each tank and cofferdam to the test head. With about half the number of tanks full, the bottom and lower side shell in the empty tanks is to be examined and the remainder of the bottom and lower side shell examined when the water is transferred.

When a preservative coating is to be applied to the internal structure of a tank, the water testing may take place after the application of the preservative, provided the structure is carefully examined to ensure that all welding and structural stiffening is completed prior to the application of the coating and any riveted shell seams are tested with a high pressure hose test on the berth before coating. The hose test of the riveted seams may be carried out from the outside to avoid wetting the tank structure.

The cause of any discoloration or disturbance of the coating is to be ascertained and any deficiencies repaired.

**5202** In lieu of the complete water testing required by 5201 a combination of a leak test and a structural test may be adopted.

The leak test is to be carried out on each tank while the vessel is on the building berth; it is to consist of a soapy solution test made while the tank is subjected to an air pressure of 0,014 N/mm<sup>2</sup> (0,14 kgf/cm<sup>2</sup>). It is recommended that the air pressure in the tank be raised to 0,021 N/mm<sup>2</sup> (0,21 kgf/cm<sup>2</sup>) with the minimum number of personnel in the vicinity of the tank and lowered to the test pressure before inspection commences.

A structural test is to be applied to one centre and two side tanks (to be selected by the Surveyor) by water testing to the test head (see 5205).

Air testing is normally to be carried out before a protective coating is applied. However, subject to careful inspection by the Surveyors, a complete protective coating



may be applied prior to air testing, except internally in way of welds made by processes other than automatic.

**5203** Water ballast and dry tanks should be tested as required for cargo tanks.

**5204** It is recommended that pump rooms be flooded to a suitable depth prior to launch. The bottom and side shell plating is to be carefully examined internally with the vessel afloat. Bulkheads not forming tank boundaries are to be leak tested as required by 5202 for tanks.

#### Test Head

**5205** The test head for cargo tanks is to be 2,45 m above the highest point of the tank, excluding hatchways; that for cofferdams is to be to the top of the hatchway.

#### Bunkers and Deep Tanks

**5206** Bunkers and deep tanks are to be tested as required by D 1934.

### Section 54

#### STRUCTURAL ARRANGEMENTS AT FORE END

##### Symbols

- 5401** L = length of ship, in metres,  
 B = moulded breadth of ship, in metres,  
 D = moulded depth, in metres, to deck at side amidships,  
 d = moulded draught, in metres,  
 S = frame or longitudinal spacing, in mm, measured along the line of the shell plating,  
 $S_1$  = spacing of web frames or transverses, in metres, measured along the line of the shell plating,  
 S = span, in metres, from span point to span point, measured along the line of the shell plating,  
 h = distance, in metres, from mid-point of span to a point 3 m above the deck height obtained from D 1705 unless stated otherwise,  
 C = a constant obtained from Fig. D 54.1.

NOTE. Spans and spacings may be measured along a straight line joining the ends of the member. Slopes smaller than 10° may be ignored.

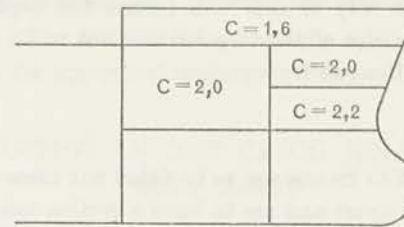


Fig. D 54.1

#### Construction

**5402** The following requirements are applicable to tankers framed either transversely or longitudinally forward of the forward end of the cargo tanks.

If a combination of transverse and longitudinal framing is adopted, equivalent strength is to be provided.

A centreline bulkhead, which may be non-oiltight, is to be fitted in the deep tank, or the longitudinal bulkheads are to extend forward to the forward deep tank bulkhead.

#### TRANSVERSE FRAMING SYSTEM

##### CONSTRUCTION IN WAY OF DEEP TANKS

##### Frame Spacing

**5403** The frame spacing in deep tanks is not, in general, to be more than 700 mm where D exceeds 8,9 m and  $\frac{1000D}{24} + 330$  mm where D does not exceed 8,9 m.

##### Bottom Construction

**5404** Floors are to be fitted at every frame. They are to have a minimum depth at the centreline of:—

$$\frac{1000D}{12} + 150 \text{ mm}$$

and a thickness of not less than  $0,666D + 2$  mm, but the thickness of the floors need not exceed 11,5 mm, and the depth of the floors need not exceed 1400 mm, but see also 5406.

Floors are to be adequately stiffened and the area of the face bar on the upper edge of the floors is not to be less than:—

$$\frac{B}{1,18} \text{ cm}^2$$

**5405** Intercostal side girders are to be fitted between the floors, in line with alternate bottom longitudinals in the forward cargo tanks, and are to be extended as far forward as practicable. They are to have the same depth as the floors.

**5406** In way of side web frames the depth of the floor and the size of the face bar are not to be less than required for the web frame.

#### Web Frames

**5407** Web frames are to be fitted not more than five frame spaces apart and are to have a section modulus not less than:—

$$\frac{I}{y} = 9 s_1 h S^2 \text{ cm}^3$$

but  $h$  is not to be taken as less than the distance from the mid-point of span to the highest point of the tank, excluding the hatchway.

#### Side Stringers

**5408** Horizontal side stringers are to be arranged in the deep tank in line with the stringers in the fore peak and are to have section moduli not less than:—

(1) supporting stringers which are to be in line with alternate fore peak stringers:—

$$\frac{I}{y} = 33,2 h s_1^2 \text{ cm}^3$$

and (2) intermediate stringers:—

$$\frac{I}{y} = 23,3 h s_1^2 \text{ cm}^3$$

but  $h$  is not to be taken as less than the distance from the stringer to the highest point of the tank, excluding the hatchway.

#### Side Framing

**5409** Deep tank side frames are to be determined in accordance with D 720 with  $H$  measured between the supporting stringers, *see* 5408(1).

#### Deep Tanks Extending to Uppermost Continuous Deck

**5410** For additional requirements when deep tanks extend to the uppermost continuous deck, *see* 5439.

### CONSTRUCTION IN DRY CARGO HOLD ABOVE DEEP TANKS

#### Web Frames

**5411** Web frames are to be fitted in the dry cargo hold in line with those in the deep tank below and are to have a section modulus not less than:—

$$\frac{I}{y} = 1,68 C s_1 h_1 d \sqrt{D} \text{ cm}^3$$

where  $h_1$  = 'tween deck height, in metres.

#### Side Stringers

**5412** Side stringers are to be fitted in dry cargo holds, spaced about 2,5 m apart and are to have the same depth as the frame. The minimum thickness of the intercostal plate web is to be 8,5 mm and the area of the face plate is to be:—

$$\frac{L}{7} + 6 \text{ cm}^2$$

#### Framing

**5413** Frames in dry cargo holds above deep tanks are to be determined in accordance with D 707 but ignoring the panting factor "f" in Fig. D 7.3.

### CONSTRUCTION IN FORE PEAKS

#### Framing

**5414** The frames in the fore peak are generally to be spaced 610 mm apart and are to be determined in accordance with D 713 and to have a vertical extent not less than required by Fig. D 7.3.

#### Floors

**5415** Floors are to be fitted at every frame, and are to have a depth and thickness not less than required by 5404, and their free edges are to be suitably stiffened.

#### Panting Beams

**5416** Tiers of panting beams are to be fitted on alternate frames in the fore peak, spaced not more than 2,0 m apart. They are to have scantlings in accordance with D 1103.

**5417** If desired, an arrangement incorporating perforated flats in lieu of tiers of panting beams may be adopted. These may be spaced 2,5 m apart and are to have scantlings as required by 5439(1).

#### Side Stringers

**5418** Side stringers determined in accordance with D 1106 are to be fitted at each tier of panting beams.

#### 'Tween Decks Above Fore Peaks

**5419** Frames in 'tween decks above fore peaks are to be determined in accordance with D 707.



## LONGITUDINAL FRAMING SYSTEM

## CONSTRUCTION IN WAY OF DEEP TANKS

## Bottom Transverses

5420 Bottom transverses in deep tanks are generally to be spaced not more than 3 m apart on ships with a length not exceeding 190 m. They are generally to be spaced not more than 3,75 m apart on ships with a length exceeding 250 m. The maximum spacing of transverses for ships of intermediate length is to be determined by interpolation. They are to have a section modulus in accordance with D 4603.

## Bottom Longitudinals

5421 Bottom longitudinals are to be fitted in line with those in the cargo tanks and are to have a section modulus in accordance with D 4402.

## Side Girders

5422 An intercostal side girder, which is to have the same depth as the bottom transverses, is to be fitted each side of the centreline.

## Centreline Girder

5423 Where the cargo tank longitudinal bulkheads are extended forward into the deep tanks and the centreline bulkhead is omitted, a centre girder having a section modulus in accordance with D 4805 is to be fitted.

## Side Transverses

5424 Side transverses are generally to be spaced not more than 3,0 m apart on ships with a length not exceeding 190 m. They are generally to be spaced not more than 3,75 m apart on ships with a length exceeding 250 m. The maximum spacing of transverses for ships of intermediate length is to be determined by interpolation. They are to have a section modulus not less than:—

$$\frac{I}{y} = 9 s_1 h S^2 \text{ cm}^3$$

Side transverses are to be in line with forecastle deck transverses.

## Side Longitudinals

5425 The section modulus of the side longitudinals is not to be less than given by the following formula, or by D 4402, whichever is the greater:—

$$\frac{I}{y} = \frac{s h S^2}{132} \text{ cm}^3$$

## Deep Tank Extending to Uppermost Continuous Deck

5426 For additional requirements when deep tanks extend to the uppermost continuous deck, see 5439.

## CONSTRUCTION IN DRY CARGO HOLDS ABOVE DEEP TANKS

## Side Transverses

5427 Side transverses in the dry cargo hold are to be in line with those in the deep tank below and are to have a section modulus not less than:—

$$\frac{I}{y} = 2,3 C s_1 h_1 d \sqrt{D} \text{ cm}^3$$

where  $h_1$  = 'tween deck height, in metres.

## Side Longitudinals

5428 The section modulus of side longitudinals in cargo holds above deep tanks is to be in accordance with 5425.

## CONSTRUCTION IN FORE PEAKS

## Bottom Construction

5429 Floors, which are generally to be spaced 610 mm apart, are to have a depth and thickness not less than required by 5404 and their free edges are to be suitably stiffened.

## Side Transverses

5430 Side transverses are generally to be spaced not more than 2,5 m apart on ships with a length not exceeding 190 m, and not more than 3,75 m on ships with a length exceeding 300 m, with intermediate values by interpolation. They are to have a section modulus not less than:—

$$\frac{I}{y} = 9 s_1 h S^2 \text{ cm}^3$$

In order to provide adequate end fixity for the side transverses, suitable transverses are to be arranged under the deck or flat in way of the side transverses, and the depth of floor in way is not to be less than that of the side transverse. The face bar of the transverse is to be continuous along the upper edge of the floor.

5431 If perforated flats are fitted to support the side transverses, their scantlings are to be in accordance with 5439(1).

## Side Longitudinals

5432 Fore peak side longitudinals are to have a section modulus not less than that required by 5425.



## 'TWEEN DECKS ABOVE FORE PEAKS

## Side Transverses

5433 Side transverses in 'tween decks above fore peaks are to be in line with the peak side transverses and are to have a section modulus not less than required by 5427.

## Side Longitudinals

5434 The section modulus of side longitudinals is to be in accordance with 5425.

## Forecastles

5435 Web frames supporting side longitudinals are to have a section modulus not less than:—

$$\frac{I}{y} = 2,1 C s_1 h d \sqrt{D} \text{ cm}^3$$

but  $h$  is not to be taken as less than the distance from the mid-point of span to the forecastle deck at side.

Their depth is not to be less than twice that of the longitudinals.

5436 Side longitudinals in the forecastle are to have a section modulus not less than:—

$$\frac{I}{y} = \frac{s S^2}{132} \left( 0,6 + \frac{D}{6} \right) \text{ cm}^3$$

5437 Pillars supporting the forecastle deck are, in general, to be spaced not more than 3,7 m apart in the region forward of 0,04L abaft the forward perpendicular.

## GENERAL

5438 The required section modulus of members attached to the shell is to be obtained about an axis parallel to the attached plating.

## Deep Tanks Extending to Uppermost Continuous Deck

5439 Where in ships exceeding 180 m in length, the deep tanks extend to the uppermost continuous deck and a centreline bulkhead only is fitted, the web frames and side transverses, which are to be in accordance with 5407 and 5424 respectively, are to be supported by one of the following methods:—

- (1) One or more perforated flats having a thickness not less than 9 mm and an area of perforations not less than 10 per cent of the total area of the flat. The section modulus of the girders and beams or longi-

tudinals on the flats may be 50 per cent of that required for an intact flat in the same position.

Suitable transverses are to be arranged under the flats in way of the side transverses,

- (2) One or more heavy side stringers having a section modulus not less than:—

$$\frac{I}{y} = 12,6 b h S^2 \text{ cm}^3$$

where  $b$  = breadth supported by the stringer, in metres, but  $h$  is not to be taken as less than the distance from the mid-point of span to the highest point of the tank, excluding the hatchway.

The ends of the stringers are to be connected to suitable stringers on the transverse bulkheads.

- (3) Cross ties having scantlings required by D 4901 and having a vertical strut fitted at about mid-length. The dimensions of the strut are to be not less than those of the uppermost cross tie and it is to be effectively connected to the deck and bottom transverse and cross ties.
- (4) Cross ties having scantlings required by D 4901 and having one or more fore and aft horizontal struts arranged to brace the cross ties between the deep tank bulkheads. The struts are to have a size appropriate to the cross ties supported.

5440 Where the longitudinal bulkheads are carried forward in deep tanks extending to the upper deck, the scantlings are to be as required by D 46, D 48 and D 49.

## Bulbous Bows

5441 The constructional arrangements required are dependent upon the shape and size of the bulb but, in general, the arrangement is to incorporate the following items:—

- (a) Large bulbous bows are to have a centreline wash bulkhead and horizontal diaphragm plates spaced not more than 1 m apart at the fore end of the bulb.
- (b) Small bulbous bows need not have a centreline wash bulkhead but are to have horizontal diaphragm plates spaced not more than 1 m apart; normally these are to be in conjunction with a centreline web.

Where the length or width of a fore peak is unusually great due to fitting a bulbous bow, additional strengthening in the form of a transverse wash bulkhead at the mid-length of the peak-bulb space may be required.



The shell plating in way of the bulb is, in general, to have a thickness required by D 1205. This increased plating should be extended to cover the areas likely to be damaged by the anchor and chain cables.

#### Continuity of Strength

5442 Continuity of strength is to be maintained at the scarfing of longitudinal and transverse framing and in cofferdams.

#### Construction of Bulkheads

5443 The scantlings of deep tank and peak tank bulkheads are to be in accordance with D 19, as applicable. For cofferdam bulkheads, *see also* D 4018.

#### Construction of Deep Tank Top

5444 The scantlings and arrangements of the deep tank top are to be as required by D 1920 and D 1921.

#### Cross-reference

5445 For construction details for primary supporting members and connections, *see* D 51.

### Section 55

#### STRUCTURAL ARRANGEMENTS AT THE AFTER END

##### 5501 Symbols

- L = length of ship, in metres,
- B = moulded breadth of ship, in metres,
- D = moulded depth, in metres, to deck at side amidships,
- D<sub>1</sub> = moulded depth, in metres, but not to be taken as greater than 20 m,
- d = moulded draught, in metres,
- s = frame or longitudinal spacing, in mm,
- s<sub>1</sub> = spacing of web frames or stringers, in metres,
- S = span, in metres,
- h = distance, in metres, from mid-point of span to upper deck at side amidships, unless stated otherwise,
- C = a constant obtained from Fig. D 55.1.

#### Construction

5502 Aft of the forward machinery space bulkhead the requirements contained in the following paragraphs are applicable to transverse or longitudinal systems of framing as appropriate. If a combination of these arrangements is adopted equivalent strength is to be provided.

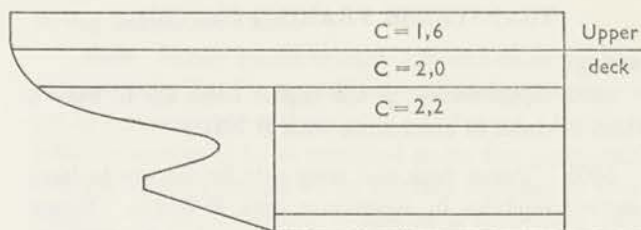


FIG. D 55.1

#### Double Bottom

5503 The double bottom is to be transversely framed. The scantlings and arrangements of the double bottom in way of the main propulsion machinery are to be suitable for its type and power. Sufficient fore and aft girders should be arranged to effectively distribute the weight of the machinery and ensure adequate rigidity, and they are to extend aft under the thrust block seat. The tank top in way of the engine foundation should be substantially increased in thickness. The main engine seating should, in general, be integral with the double bottom structure; this particularly applies to higher power diesel and turbine installations. The general scantlings of the double bottom clear of the main machinery are to be not less than as follows:—

Minimum depth of centre girder:

$$D_{DB} = \frac{1000 B}{36} + 205 \sqrt{d} \text{ mm}$$

Minimum thickness of centre girder:

$$0,008 D_{DB} + 4 \text{ mm}$$

but may be 10 per cent less at aft end where clear of main engine seating.

Minimum thickness of non-watertight floors and side girders:

$$0,008 D_{DB} + 1 \text{ mm}$$

Minimum thickness of watertight floors = non-watertight thickness + 2 mm but need not exceed 15 mm.

Section modulus of watertight floor stiffeners is not to be less than:

$$\frac{I}{y} = \frac{D_{DB}^2 h_{DB} s_{DB}}{185 \times 10^6} \text{ cm}^3$$

where  $h_{DB}$  = head from top of inner bottom to top of overflow pipe, in metres,

$s_{DB}$  = stiffener spacing, in mm.

Minimum thickness of tank top plating:

$$0,0015 (s + 660) \sqrt[4]{Ld} \text{ mm}$$



## TRANSVERSE FRAMING SYSTEM

## Framing

**5504** Main frames in the engine room are to have a section modulus in accordance with D 707(1).

**5505** 'Tween deck and poop side frames are to have a section modulus in accordance with D 707(1). Where horizontal stringers having scantlings required by 5508 are fitted, they may be considered to be decks for the purpose of calculating the required frame section modulus.

**5506** Aft of the line of the after peak bulkhead, peak and 'tween deck frames are to be spaced as required by D 706. Peak frames are to have a section modulus in accordance with D 713, and 'tween deck and poop frames aft of the line of the after peak bulkhead are to have a section modulus in accordance with D 707(3).

## Web Frame and Side Stringers

**5507** Web frames are to be fitted in the machinery space below the lowest deck or flat, not more than five frame spaces apart.

**5508** Where a horizontal stringer giving full support to the side framing is fitted below the lowest deck or flat, the web frame section modulus is to be based on a stress of 93,2 N/mm<sup>2</sup> (9,5 kgf/mm<sup>2</sup>), assuming fixed ends and point loading from the stringer, taking the head to upper deck at side amidships.

The section modulus of the stringer is not to be less than:—

$$7,75 s_1 h S^2 \text{ cm}^3$$

**5509** Where a horizontal stringer giving partial support to the side framing is fitted below the lowest deck or flat, the web frames are to have a section modulus not less than:—

$$7,75 s_1 h S^2 \text{ cm}^3$$

The section modulus of the stringer is not to be less than:—

$$3,8 s_1 h S^2 \text{ cm}^3$$

**5510** Where no stringer is fitted the section modulus of the web frames is not to be less than:—

$$5,0 s_1 h S^2 \text{ cm}^3$$

**5511** The minimum depth of web frames in 5508, 5509 and 5510 is not to be less than 2,5 times the depth of the adjacent side frames.

The thicknesses of web frames and horizontal stringer webs are to be the same.

**5512** Above the lowest deck, or equivalent, webs are to be fitted in line with the web frames below the deck and are to extend to the uppermost continuous deck. The section modulus of these web frames is not to be less than:—

$$1,67 C s_1 S d \sqrt{D} \text{ cm}^3$$

Where there is no midship erection and all accommodation is fitted aft, sufficient web frames or partial bulkheads are to be fitted in the poop and in the superstructure above to ensure adequate transverse rigidity.

These webs should, in general, be in line with the web frames below the upper deck.

## LONGITUDINAL FRAMING SYSTEM

## Longitudinal Framing in Machinery Space

**5513** In the machinery space the section modulus of the side longitudinals is not to be less than:—

$$\frac{I}{y} = \frac{s S^2}{153,5} \left( h + \frac{D_1}{6} \right) \text{ cm}^3$$

where h is not to be less than 0,9 m.

## Web Frames

**5514** The section modulus of transverse webs in machinery spaces situated below the lowest deck or equivalent flat and supporting side longitudinals is not to be less than:—

$$\frac{I}{y} = 10 s_1 h S^2 \text{ cm}^3$$

The spacing of web frames is not to be more than required by 5507.

**5515** The section modulus of transverse webs in oil fuel bunkers adjacent to machinery spaces and situated above the lowest deck or equivalent, is not to be less than that required by D 4607 and D 4608 with  $L = 12H$  or 90 m whichever is the greater, where H is the tank depth, in metres.

**5516** In spaces of normal 'tween deck height situated above the lowest deck or equivalent clear of oil fuel bunkers, webs are to be fitted in line with the web frames below the deck and are to extend to the uppermost continuous deck. The section modulus of the web frames is to be not less than:—

$$\frac{I}{y} = 2,1 C s_1 S d \sqrt{D} \text{ cm}^3$$

**5517** When longitudinal framing is adopted above the after peak, transverse webs are to be fitted in the 'tween decks not more than four frame spaces apart.



The section modulus of these webs is not to be less than:—

$$\frac{I}{y} = 2,1 C S_1 S d \sqrt{D} \text{ cm}^3$$

5518 The section modulus of side longitudinals above the after peak and abaft the after peak bulkhead is not to be less than:—

$$\frac{I}{y} = \frac{S S^2}{117,5} \left( h + \frac{D_1}{6} \right) \text{ cm}^3$$

where  $h$  is not to be less than 3 m. Where, due to the shape of the vessel, the spacing of longitudinal exceeds 915 mm, intermediate longitudinals are to be fitted.

#### Poop Side Longitudinals

5519 Poop side longitudinals are to have a section modulus not less than:—

$$\frac{I}{y} = \frac{S S^2}{153,5} \left( 0,6 + \frac{D_1}{6} \right) \text{ cm}^3$$

#### GENERAL

##### After Peak

5520 Floors in the after peak and counter are to have a thickness not less than that required by 5503. They are to be stiffened by flat bars or rolled sections of adequate size and spacing, bearing in mind possible vibratory forces which may arise in this region from the propeller. A centre-line wash bulkhead having the same thickness as the floors is to be arranged in the after peak tank and counter. When transverse framing in accordance with 5505 is fitted above the after peak, web frames or their equivalent are to be arranged in the 'tween decks at every fourth frame abaft the after peak bulkhead.

5521 Frames, floors, stringers, girders, stiffeners and wash bulkheads in the after peak, or on the after peak bulkhead are not to be scalloped and the connection to shell or bulkhead is to be by double continuous welds.

##### Decks

5522 Lower decks or flats are to have sufficient strength and adequate end fixity when they are intended to support webs and side frames.

#### Strong Beams and Pillars

5523 Strong beams or other efficient cross ties are, in general, to be fitted in way of large machinery openings and are to be associated with suitable web frames. An efficient pillaring system is to be provided under the engine casing and the casing sides are to be suitably stiffened in way of pillars. When the casing is used as a supporting girder, suitable compensation is to be provided for openings.

#### Oil Fuel Bunkers

5524 The structural arrangements in the cargo tanks are to be maintained in oil fuel bunkers at the fore end of the machinery space where this falls within 0,5L amidships. The scantlings are to be as required for cargo tanks, but the scantlings of cofferdam bulkheads where they are not cargo tank bulkheads are to comply with the requirements of D 4018 for plating and may have stiffeners as required by D 19.

#### Continuity of Strength

5525 Continuity of strength is to be maintained at the scarfing of longitudinal and transverse framing and in cofferdams.

The longitudinal deck framing is to extend one-third of the breadth of the ship into the poop. The side longitudinals are to extend abaft the poop front and the terminating positions of the longitudinal systems at sides and bottoms are to be staggered.

The longitudinal bulkheads are to extend well aft into the engine room and are to be suitably tapered at their ends.

#### Connections

5526 Web frames are to be suitably connected at top and bottom to members of adequate stiffness. Stringers are to be bracketed to the bulkheads. The stringer web and face plate are to be efficiently connected to the web frames.

#### Cross-references

5527 For geometric properties of sections, *see* D 128.

For construction details for primary supporting members and connections, *see* D 51.



## DREDGERS, HOPPER DREDGERS, SAND CARRIERS, HOPPER BARGES AND RECLAMATION CRAFT

### Section 80

#### GENERAL

##### Application

**8001** These Rules apply to non-self-propelled and self-propelled steel hopper barges and to steel dredgers, hopper dredgers, sand carriers and reclamation craft constructed with their main propulsion machinery and/or sand pumps or dredging machinery (other than grab cranes) placed within the main hull structure.

Ships which have their machinery placed on a shallow raft rather than within a hull will have their scantlings specially considered.

**8002** The scantlings and arrangements of Dredgers, Hopper Dredgers, Sand Carriers, Hopper Barges and Reclamation Craft are to be as required by D 1 to D 34, except where otherwise stated in D 80 to D 90.

**8003** Ships of unusual form or proportions or intended for unusual dredging methods will receive individual consideration on the basis of the general standards of the Rules.

Dredgers which resemble drilling rigs, or similar offshore structures, in their design or mode of operation, will be considered under the Rules for such structures.

**8004** If the ratio of length to depth exceeds sixteen or the ratio of breadth to depth exceeds four, increased scantlings may be required to ensure that the hull deflections do not become excessive.

##### Stability

**8005** Attention is drawn to the thixotropic properties of certain types of dredged material such that the ship's motions can cause the spoil to shift within a hopper space resulting in undesirable changes in trim or angles of heel. This can be particularly dangerous in vessels with closed top hoppers. *See also* 8008 (j).

##### Distribution of Continuous Longitudinal Material

**8006** The midship scantlings are generally to extend over 0,4L amidships, or over the length of the hoppers, whichever is the greater, and are to be reduced gradually to

those permitted at the ends except where otherwise required by the Rules. Arrangements are to be made to avoid a sudden change in section at the ends of longitudinal hopper or well bulkheads.

##### Equivalents

**8007** Alternative arrangements or fittings which are considered to be equivalent to the Rule requirements will be accepted. Scantlings based on approved computer grillage calculations may be accepted if the stress and deflection values are considered suitable for the items concerned. *See* D 8013.

##### Plans

**8008** Plans and calculations, as applicable, covering the following items are to be submitted in addition to the normal ship plans:—

- (a) Sections through hoppers, wells, pump rooms and dredging machinery spaces.
- (b) Hopper and well bulkheads and associated weirs.
- (c) Scarfing arrangements at hopper and well ends.
- (d) Outline arrangement and main scantlings of "A" frames, gantries, positioning spuds, hopper doors and similar items, the strength and integrity of which directly affect the hull structure of the vessel.
- (e) Support structure in way of "A" frames, positioning spuds and other dredging structures.
- (f) Seats of dredging machinery and pumps.
- (g) If dredging equipment is stored during voyages, plans of any special arrangements for dismantling, storage and re-assembly.
- (h) Longitudinal strength calculations, including shear stress values and details of proposed loading conditions including densities of spoil.
- (j) A full set of stability data which is to be placed on board the ship. *See* B 101.

When it is intended that ships are to be classed 100A1 or 100A1 restricted service, but while operating in sheltered



waters or within easy access of such waters, in reasonable weather (see B 130 to B 132), they may be loaded to a draught greater than that which would be assigned under the International Load Line Convention for unrestricted international or similar voyages, then particulars of the draught desired and the associated loading conditions and structural arrangements are to be submitted for approval. Stability data for these deep draughts is to be included with that required under (j) above, *but see* B 101.

### Definitions

**8009** Length  $L$  is the distance, in metres, on the load waterline at draught  $d$ , from the foreside of the stem to the afterside of the rudderpost, or to the centre of the rudderstock if there is no rudderpost.  $L$  is not to be less than 96 per cent and need not be greater than 97 per cent of the extreme length on the summer load waterline.

On ships classed A1 protected waters service for which a load waterline is not established by the International Load Line Convention method, the length is to be measured on the deepest waterline at which the ship is designed to operate.

On sea-going vessels with unusual stern arrangement, or with an unusual bow arrangement associated with a dredging draught in excess of the summer load line draught, the length  $L$  will be specially considered.

**8010** Breadth  $B$  is the greatest moulded breadth, in metres, excluding any localized bulge on the hull associated with the attachment or handling of the dredging gear.

**8011** Draught  $d$  is the summer draught in metres, as established by the method described in the International Load Line Convention, measured from top of keel.

**8012** Draught  $d_m$  is the maximum draught in metres, at which the ship is designed to operate. It is to be measured amidships from the top of keel and is not to be taken as less than  $d$ .

### Direct Calculations

**8013** Consideration will be given to any proposals to base the scantlings of any ships covered by these Sections on direct calculations. In such cases the proposed loadings, stress levels and corrosion allowances are to be submitted for consideration at an early stage in the design. When such calculations are made for major items such as longitudinal bulkheads, main transverses, etc., the Society may also require that the effect of shear deflections be taken into account.

## Section 81

### LONGITUDINAL STRENGTH

**8101**  $L$  = length of ship as defined in D 8009, in metres,

$C_b$  = the moulded block coefficient at dredging draught  $d_m$  or  $0,045L$ , whichever is the greater but is not to be taken as less than  $0,60$ .

The block coefficient is to be determined using the length  $L$ . *See also* 8104.

$C_{b1}$  = the moulded block coefficient at the ballast or part loaded draught, but is not to be taken as less than  $0,60$ . The block coefficient is to be determined using length  $L$ . *See also* 8104.

$B$  = moulded breadth, in metres,

$SWBM_D$  = the maximum still water bending moment under dredging conditions, in  $kN\ m$  (tonne-f m), at draught  $d_m$ ,

$SWBM_B$  = the maximum still water bending moment, in  $kN\ m$  (tonne-f m), hogging or sagging in ballast or part loaded condition at draught  $d$  or less,

$f$  =  $0,65$  for ships classed 100A1 without restriction having a length  $120\ m$  or less. Ships over  $120\ m$  will be specially considered.

=  $0,60$  for ships classed 100A1 restricted service,

=  $0,55$  for ships classed A1 protected waters service,

$F$  =  $0,44$  for ships classed 100A1 without restriction,

=  $0,32$  for ships classed 100A1 restricted service,

=  $0,17$  for ships classed A1 protected waters service,

$K$  = values given in Table D 81.1,

$M = f K B (C_b + 0,7) \times 10^5\ cm^3$

$M_1 = 0,65 K B (C_{b1} + 0,7) \times 10^5\ cm^3$

### Calculations

**8102** The still water bending moment calculations for the homogeneous and, if applicable, the non-homogeneous load and part-loaded conditions and for the ballast conditions are to be submitted.

The assumed lightweight and its distribution are to be submitted and the disposition of fuel, stores and fresh



TABLE D 81.1 VALUES OF K

LENGTH L	K	DIFFERENCE IN K PER 1 m DIFFERENCE IN L	LENGTH L	K	DIFFERENCE IN K PER 1 m DIFFERENCE IN L
metres			metres		
90	0,747		150	2,382	0,0344
95	0,865	0,0236	155	2,563	0,0362
100	0,985	0,0240	160	2,752	0,0378
105	1,106	0,0242	165	2,950	0,0396
110	1,228	0,0244	170	3,157	0,0414
115	1,351	0,0246	175	3,372	0,0430
120	1,476	0,0250	180	3,596	0,0448
125	1,606	0,0260	185	3,830	0,0468
130	1,744	0,0276	190	4,074	0,0488
135	1,891	0,0294	195	4,329	0,0510
140	2,046	0,0310	200	4,594	0,0530
145	2,210	0,0328			
		0,0344			

water used in the loading conditions is to represent typical dredging conditions.

Where a dredger is arranged with two hoppers, account is to be taken in the calculation of  $SWBM_B$  of either one of these hoppers being empty, unless such loading is expressly forbidden in the Loading Manual supplied to the ship.

The Loading Manual is to be submitted for approval of the loading conditions shown therein.

#### Section Modulus

**8103** The section modulus at deck at side is not to be less than the greatest of the values given in Table D 81.2 as applicable.

**8104** When the still water bending moment and block coefficient are being calculated, any water within hopper spaces or sand holds should be regarded as added weight, while that in dredging ladder wells and spud wells should be regarded as lost buoyancy.

**8105** The section modulus at keel is to be not less than 7 per cent greater than that required by 8103 at deck at side.

**8106** The section modulus at the top of continuous coamings may be 5 per cent less than that required at deck at side by 8103. The lever  $y$  used to calculate this modulus is to be measured to the top of coaming. The modulus requirements of 8103 must still be complied with at deck at side.

**8107** Centreline box keels within the hopper spaces may normally be regarded as 100 per cent effective provided that they are effectively scarfed to the vertical keels or equivalent structure at each end of the hopper spaces.

Continuous coamings fitted above longitudinal bulkheads may normally be regarded as 100 per cent effective. Continuous coamings which are not supported by longitudinal bulkheads are to be assumed 80 per cent effective, the full modulus required by 8105 must, however, still be obtained. Where a long superstructure or deckhouse is fitted extending within the 0,5L amidships, the requirements for longitudinal strength in the hull and erection will be considered in each case.

#### Extent of Midship Modulus

**8108** The modulus derived as above is generally to extend over the full length of all hoppers and sand holds in hopper dredgers, hopper barges and sand carriers.



TABLE D 81.2

MODULUS AT DECK AT SIDE	APPLICABILITY
(a) $M \text{ cm}^3$	all ships
(b) $F M + 7,34 \text{ SWBM}_D \text{ cm}^3$ ( $F M + 72 \text{ SWBM}_D \text{ cm}^3$ )	all ships
(c) $0,44 M_1 + 9,38 \text{ SWBM}_B (C_{b1} + 0,2) \text{ cm}^3$ $(0,44 M_1 + 92 \text{ SWBM}_B (C_{b1} + 0,2) \text{ cm}^3)$ or $0,88 M_1 + 4,64 \text{ SWBM}_B (C_{b1} + 0,2) \text{ cm}^3$ $(0,88 M_1 + 45,5 \text{ SWBM}_B (C_{b1} + 0,2) \text{ cm}^3)$ whichever is the greater	(i) all ships classed 100A1 without restriction, (ii) sand carriers classed 100A1, restricted service when $d_m > d$ .

On other dredgers and reclamation craft the modulus is generally to be maintained for  $0,4L$  amidships, but the extent may need to be increased if the design and loading condition of a particular ship results in its maximum bending moment occurring other than at amidships.

**8109** If any dredging equipment has to be unshipped, lowered or otherwise specially arranged or stowed before the vessel proceeds on a sea-going voyage, this fact is to be marked on the data sheets and diagrams submitted for approval and is to be clearly stated in the loading booklet supplied to the ship.

## Section 82

### DECK PLATING

#### Symbols

**8201**  $L$  = length of ship, in metres,

$t$  = plate thickness, in mm,

$s$  = spacing of beams or longitudinals, in mm.

#### Strength Deck Outside Line of Openings

**8202** Dredgers, hopper dredgers and hopper barges classed 100A1 without a restricted service notation are to have the minimum thicknesses required by D 1 to D 34 increased by 2 mm for those areas of the strength deck outside line of openings which are exposed to the weather.

Ships classed 100A1 restricted service should have scantlings exactly as in D 1 to D 34.

Ships classed A1 protected waters service may have the minimum thicknesses as given in D 1 to D 34 for all plating outside line of openings reduced by 1 mm, with an overall minimum of 5 mm.

**8203** The minimum value of  $s$  used in the formulæ for deck plating thickness may be taken as 550 mm for all ships with a restricted service notation.

#### Strength Deck Plating Forward and Within Line of Openings

**8204** The thickness of strength deck plating for  $0,1L$  from the ends of the vessel and also amidships within the line of openings is not to be less than that for cargo ships, but in addition, such plating that is within  $0,4L$  amidships

is to have a thickness not less than  $t = \frac{s}{100} \text{ mm}$

#### Strengthening for Local Impacts

**8205** Additional thickness may be required for those areas of deck which are liable to be subjected to regular, heavy, impact loads such as could occur when maintaining or inspecting large items of dredging gear, etc.

It is recommended that consideration be given to increasing the plating thickness in these areas to

$$t = \frac{s}{50} \text{ mm}$$

with a minimum  $t = 10 \text{ mm}$ .



## Section 83

## SHELL PLATING

## Symbols

- 8301 L = length of ship, in metres,  
 D = depth moulded to the uppermost continuous deck, in metres,  
 s = spacing of frames or longitudinals, in mm,  
 B = moulded breadth, in metres,  
 d = draught (*see* D 8011) in metres,  
 d<sub>m</sub> = dredging draught (*see* D 8012), in metres.

## Keel

8302 Where there is a centreline well, or where hopper doors are fitted on the vessel's centreline, i.e. where no centreline box keel is fitted in a hopper, then a keel strake is to be fitted on each side of the well or hopper door opening. The width of each keel strake is to be not less than half that required for a centreline keel nor less than 400 mm. The thickness of each keel strake is to be not less than the thickness required for a centreline keel.

## Bottom Shell

8303 The minimum thickness of bottom shell plating amidships on hopper dredgers and hopper barges classed 100A1 without service restrictions is to be 15 per cent greater than that required for dry cargo ships. The thickness of bottom shell plating on vessels classed A1 protected waters service is to be not less than:—

$$\frac{sL\sqrt{D}}{20\,000} + 5\text{ mm}$$

or that required for dry cargo ships, whichever is the lesser, but with an overall minimum thickness of 6 mm.

## Operating Aground

8304 Dredgers, hopper dredgers and reclamation craft intended or expected to operate while aground or to be frequently permitted to ground during the course of service are to have shell plating thicknesses increased by 20 per cent over the dry cargo ship minimum requirements, and in no case is the thickness so derived to be less than 8 mm.

Unless specifically stated otherwise by the Owner, it should be assumed that non-self-propelled reclamation craft, dredgers of the non-self-propelled hydraulic pipeline cutterhead type and non-self-propelled dipper bucket type are also intended to operate aground.

## Ships with Chines

8305 On ships arranged with two chines each side, the bilge plating should generally be calculated from the bottom plating formulæ.

On hard chine ships flanged chines will not generally be approved, but where a chine is formed by knuckling the shell plating, the radius of curvature, measured on the inside of the plate, is not to be less than ten times the plate thickness.

8306 Where a solid round chine bar is fitted the bar diameter is to be not less than three times the thickness of the thickest abutting plate.

8307 Where welded chines are used the welding is to be built up as necessary to ensure that the shell plating thickness is maintained across the weld.

## Extent of Midship Thickness Requirements

8308 Where hoppers extend outside 0,4L amidships the thicknesses required for the bottom shell amidships are to be maintained for at least two frame spaces beyond the ends of the hoppers before being tapered to the end thicknesses.

## Bottom Openings

8309 The corners of hopper door openings and of bucket and ladder wells are generally to be parabolic or elliptical.

The arrangement of hopper and well corners within 0,5L amidships should generally be as required for deck hatch corners. The sealing arrangements for hopper doors may lie within the line of the corners provided the construction is such as to avoid high stress concentrations in the structure.

## Side Shell

8310 On ships classed A1 protected waters service the thickness of the side shell throughout, including at ends, may be reduced 20 per cent from that required by D 5 provided that the shear stress requirement of 8312 is satisfied.

8311 Where high compressive loads occur in the shear strake the thickness may require to be increased to minimize the likelihood of buckling.

8312 For side shell shear stress requirements for sea-going ships, *see* D 332 and subsequent paragraphs.

## Swim Ends

8313 The plating of swim ends is to have a thickness not less than that required for the bottom shell up to the



waterline at draught  $d$ . It is to have a thickness not less than that required for side shell in the areas more than 1 m above the waterline at draught  $d_m$ . In intermediate areas the thickness may be tapered from the bottom to the side shell requirements.

## Section 84

### BOTTOM STRUCTURE

#### Symbols

- 8401  $L$  = length of ship, in metres,  
 $B$  = breadth of ship, in metres,  
 $D$  = depth of ship, in metres,  
 $d_m$  = dredging draught (see D 8012), in metres,  
 $s$  = frame spacing, in mm,  
 $S_1$  = spacing of transverses, in metres, and is not to be taken as less than 1,85 m,  
 $S_2$  = span of floors, in metres, measured between support points.

#### Application

8402 This Section provides for longitudinal or transverse framing of the bottom structure of ships with single or double bottoms. However, a double bottom is to be provided as follows:—

- (a) on trailing suction hopper dredgers:—
  - (i) between the collision bulkhead and the forward end of the hopper or well,
  - (ii) between the after bulkhead of the forward hopper and forward bulkhead of the after hopper on twin hopper ships.
- (b) on trailing suction side caster dredgers not fitted with hoppers:—

for  $0,25L$  measured aft from the collision bulkhead.

The double bottom may, however, be interrupted locally, or fitted with wells in way of dredging pumps and other equipment. Where such openings are large their scantlings and arrangements will be specially considered.

### DOUBLE BOTTOMS

8403 The Rule thickness of centre girders may be reduced by 2 mm on vessels classed A1 protected waters service.

The minimum scantlings applicable to dry cargo ships are, however, to be complied with.

8404 Special consideration will be given to the scantlings of floors, longitudinals and plating supporting the bottom of spaces intended to carry spoil on sand carriers.

8405 The Rule thickness of side girders may be reduced by 1,0 mm on ships classed for restricted service.

8406 The requirements of D 10 (Strengthening of Bottom Forward) need not be applied to ships classed A1 protected waters service.

8407 For ships operating aground, see D 8408 and D 8412 to D 8414.

#### Double Bottom Structure with Transverse Framing

8408 Plate floors may be fitted at every frame or may be spaced not more than 3,05 m apart with the shell and inner bottom plating between these floors supported by bracket floors. However, plate floors are to be fitted at every frame in the following areas:—

- (a) as required for dry cargo ships, see D 910,
- (b) below holds and hoppers from which dredged material will be discharged by grabs,
- (c) in main propulsion and dredging machinery rooms and in peak tanks,
- (d) throughout in vessels intended to operate while aground,
- (e) for three frame spaces at the ends of hoppers and dredging wells.

#### Double Bottom Structure with Longitudinal Framing

8409 The section modulus of bottom longitudinals and inner bottom longitudinals is not to be less than:—

$$\frac{I}{y} = \frac{S_1^2 s H}{K} \text{ cm}^3$$

where  $H$  = (a)  $D$  for bottom longitudinals on ships classed 100A1 or 100A1 restricted service,

(b)  $d_m$  for bottom longitudinals on ships classed A1 protected waters service,

(c) height, in metres, from the tank top to the deck at side, for inner bottom longitudinals (but need not exceed  $d_m$  on ships classed A1 protected waters service) except that, in sand carriers,  $H$  for inner bottom longitudinals is to be measured to the upper weir in spaces intended to carry dredged spoil,

$K$  = (a) 77 for inner bottom longitudinals below holds intended for dredged spoil,



- (b) 74 for bottom longitudinals on ships expected to operate while aground,
- (c) 120 for (i) bottom longitudinals for ships classed 100A1 and 100A1 restricted service other than ships expected to operate while aground, and (ii) inner bottom longitudinals in machinery spaces on ships classed 100A1,
- (d) 150 for bottom longitudinals on ships classed A1 protected waters service and for inner bottom longitudinals other than (i) those below holds intended for dredged spoil, and (ii) in machinery spaces on ships classed 100A1.

**8410** The spacing of transverses is generally to be as for dry cargo ships but is not to exceed 4,0 m. Below main dredging machinery the transverses are generally to be spaced not more than 1000 mm apart.

**8411** The ends of longitudinal girders under dredging machinery are to be tapered off or efficiently scarfed into other longitudinal structural items.

#### Strengthening for Operating Aground

**8412** Ships intended or expected to operate while aground or to be frequently permitted to ground during the course of service are to have their double bottom structure additionally strengthened.

**8413** Where such ships are transversely framed, the floors in double bottoms are to be plate floors throughout and vertical stiffening is to be arranged to give panel widths not exceeding 1,25 m. Additional side girders are to be fitted such that the girder spacing does not exceed 2,5 m and the additional stiffeners required by D 515 are to be extended and fitted throughout the flat of bottom.

Where the span of floors between a hopper space and the ship's side exceeds 3,75 m a longitudinal girder is to be fitted.

**8414** Where ships are longitudinally framed, the plate floors are generally to be spaced not more than 1,85 m apart.

These floors are to be associated with longitudinal girders spaced not more than 2,5 m apart.

#### SINGLE BOTTOMS TRANSVERSELY FRAMED

**8415** Abreast of dredging wells and hoppers the minimum depth of floor at its inboard end is not to be less than  $20 (B + S_2 + 2 d_m)$  mm.

The thickness of the web and area of the face plate are to be as required by SD 8 in the *Rules for Small Ships*.

**8416** The scantlings of single bottom floors, extending the full width of the ship, are to comply with SD 8 (in the *Rules for Small Ships*).

Floors below dredging pumps or similar items which could induce large concentrated loads or large dynamic forces, may require to be of increased strength.

Floors may be recessed locally in way of dredging pumps, etc., provided suitable compensation is arranged.

**8417** The spacing of intercostals and longitudinal side girders is to be such as to ensure continuity of strength at bulkheads, ends of hoppers and wells and at ends of machinery seats so far as is practicable. (See also SD 8 in the *Rules for Small Ships*.) An intercostal is to be fitted in the buoyancy space abreast the hopper opening when the distance between the hopper opening and the ship's side exceeds 4,0 m.

#### Strengthening for Operating Aground

**8418** Ships intended or expected to operate while aground or to be frequently permitted to ground during the course of service are to have their bottom structure additionally strengthened as follows:—

- (a) Floors are to be fitted with vertical stiffeners spaced not more than 1,5 m apart.
- (b) Side girders are to be spaced not more than 2,2 m apart. The additional longitudinals required by D 515 are to be extended all fore and aft throughout the flat of bottom.

#### SINGLE BOTTOMS LONGITUDINALLY FRAMED

**8419** The section modulus of bottom longitudinals is not to be less than:—

$$\frac{I}{y} = \frac{S_1^2 s D}{K} \text{ cm}^3$$

where K = (a) 74 on ships expected to operate while aground,

- (b) 120 on ships classed 100A1 or 100A1 restricted service other than those expected to operate while aground,
- (c) 150 on ships classed A1 protected waters service other than those expected to operate while aground.

**8420** The spacing of transverses is generally not to exceed 4,0 m.



These transverses are to be supplemented by brackets:—

- (a) on the ship's centreline, or each side of dredging wells where there is no structure on the centreline, the brackets are to be spaced not more than 1,25 m apart and are to extend outboard to the first longitudinal, port and starboard. The longitudinals supported by the brackets may be calculated using a nominal transverse spacing of 1,60 m.
- (b) on ships where the sides are transversely framed, the brackets are to be fitted at every frame and are to extend inboard to the first longitudinal on the flat of bottom. This longitudinal is to be based on a span equal to the spacing of the transverses.

The thickness of these intermediate brackets is not to be less than:—

$$0,25B + 1,85\sqrt{d_m} \text{ mm}$$

**8421** In areas of high shear loading, the thickness and stiffening of the web plates on transverses, etc., may have to be increased.

The depth of transverses is to be not less than 2,5 times the depth of the slot for the bottom longitudinals and the thickness of the web plates is to be not less than 8 mm.

**8422** Bottom transverses in hopper side buoyancy tanks in way of hopper cross ties are to have a depth of not less than  $28B + 205\sqrt{d_m}$  mm.

Their arrangement, scantlings and end connections are to be such as to provide proper continuity of strength across the ship.

**8423** The transverses are to be fitted with stiffeners in way of every shell longitudinal. The stiffeners should, in general, be equivalent to flat bars with a depth one-eighth of the transverse at that point and a thickness not less than the thickness of the transverse.

#### Strengthening for Operating Aground

**8424** On ships intended to operate while aground the bilge longitudinals are to be as required for bottom longitudinals.

**8425** The stiffening on the web plates of transverses is to be such that, in general, the dimensions of the panels adjacent to the shell plating do not exceed 80 times the actual web thickness.

**8426** Ships intended to operate while aground are to have additional side girders fitted such that their spacing does not exceed 2,2 m and the spacing of transverses is to be closed up, or intermediate transverses are to be fitted, to give spacing of transverses not exceeding 2,5 m outboard of wells or 1,85 m elsewhere.

### Section 85

#### HOPPER AND WELL STRUCTURE

##### Symbols

- 8501**  $L$  = length of ship, in metres,
- $B$  = breadth of ship, in metres,
- $D$  = moulded depth to uppermost continuous deck, in metres,
- $h$  = head, in metres, measured to the upper edge of the hatch or hopper coaming or to 0,5 m above the sill of the uppermost overflow weir, whichever is the lower,
- $t$  = plate thickness, in mm,
- $d_m$  = dredging draught (*see* D 8012), in metres,
- $s$  = spacing or panel width, in mm,
- $\rho$  = relative density of stowage rate of water or hopper contents as applicable. The value assumed for the relative density of dredged spoil should generally not be less than 1,86. The value used in the calculation of scantlings is to be clearly marked on the relative plans.
- $A_1$  = cross-sectional area of flange or stiffener, in  $\text{cm}^2$ , including coaming plating,
- $l_e$  = spacing of brackets, in metres, required by 8525.

##### Application

**8502** This Section provides for:—

- (a) horizontally and vertically stiffened boundary bulkheads to hoppers, and holds intended for dredged spoil, to ladder wells and to spud wells,
- (b) protection against flooding in the event of the ladder well or adjacent bottom plating being damaged by objects dredged up by bucket dredgers, and
- (c) continuity of transverse strength in hoppers and wing tanks abreast of hoppers.



**Hopper and Well Bulkheads****Plating**

**8503** The thickness of hopper and sand carrier hold bulkheads is to be as required by D 19 for deep tanks, with a minimum of:

- 10 mm for grab dredgers, and
- 8,5 mm for other vessels.

These thickness requirements also apply to the plating of watertight box keels as well as to hopper end and side bulkheads.

The value of  $\rho$  used in the calculations and the height(s) of the overflow weir(s) are to be clearly shown on the midship section plan.

Attention is drawn to the high rate of wear that can occur on hopper bulkheads and it is recommended that an additional corrosion allowance of 3 mm be added on areas subject to particularly onerous conditions. When such an allowance is added, the fact should be marked on the relevant plans.

**8504** The thickness of plating forming the sides and ends of bucket ladder wells is not to be less than:—

$$0,0055 s \sqrt{d_m} + 3,0 \text{ mm}$$

In no case, however, is the side plating to have a thickness less than 12 mm nor is the well end plating to have a thickness less than 8,5 mm. Plating forming the boundaries of suction pipe ladder wells is generally to be as required for shell plating. Corrosion allowance on well end plating below bucket ladders may be 2 mm.

**8505** The thickness of hopper bulkheads and of ladder well bulkheads may require to be increased where high shear forces are present.

**8506** Bulkheads forming the boundaries of spud wells are to be of increased strength. Each case will be considered on its merits, but in general such bulkheads should have a thickness of not less than 12 mm.

**Stiffeners**

**8507** Stiffeners are generally to be as required by D 19 for deep tanks, but with  $h$  and  $\rho$  as defined in 8501.

End connections are generally to be as required by D 18.

**8508** Structure supporting spud well plating and bulkheads below and in way of "A" frames and dredging machinery supports is to be of substantial construction, account being taken of the dynamic loads likely to occur with the dredging machinery in operation.

**Girders and Web Frames**

**8509** The section modulus and inertia of horizontal girders supporting stiffeners on hopper and ladder well boundaries are, in general, to be as required by D 19 for deep tanks, with  $h$  and  $\rho$  as defined in 8501 and with span  $S_G$ , for horizontal girders supporting vertical stiffeners on longitudinal bulkheads measured between bulkhead bracket and bulkhead bracket, i.e. ignoring any struts which may be fitted between hopper girder and shell stringer.

Alternatively, the section modulus of these horizontal girders may be reduced by 40 per cent from the formula value if struts are fitted on alternate frames between the hopper girder and a shell stringer. These struts should generally be horizontal and are to have a sectional area as required for pillars by D 14 with  $\rho$  assumed 0,537 m<sup>3</sup>/tonne and  $h$  measured from the inboard end of the strut to the height defined in 8501.

**8510** Web frames and girders are to be as required by D 19 with  $\rho$  and  $h$  as defined in 8501.

**8511** Where non-watertight bulkheads are fitted in the side buoyancy tanks in hopper dredgers, sand carriers or hopper barges, the thickness of the plating is to be not less than:—

- (a) 6,5 mm or
  - (b)  $5,35 \text{ mm} + 0,024L \text{ mm}$ ,
- whichever is the greater.

Where the bulkhead is in the form of a wash bulkhead, the openings should be arranged so that, in general, the distance from lightening holes to any slots cut to accommodate side shell or bulkhead longitudinals is at least equal to 1,5 times the depth of the slot. The edges of large openings are to be stiffened.

**Ladder Well Cofferdams**

**8512** Ladder wells of trailing suction dredgers are to be isolated from the remainder of the dredger's structure by local cofferdams at least 600 mm wide, or are to be otherwise protected so as to prevent serious flooding due to the well side plating being breached by the ladder structure should this be damaged in service.

Ladder wells of bucket dredgers are to be isolated by cofferdams, the extent and widths of which are to be sufficient to contain any damage to the well side bulkheads or bottom shell plating that could result from the impact of large objects brought up in the dredge buckets. In way of the buckets the cofferdam may be extended outboard in the form of a local watertight double bottom.



**Continuity of Strength**

**8513** Arrangements are to be made to ensure continuity of strength at the ends of longitudinal hopper and well side bulkheads. In general, the design should be such that the bulkheads are connected to bottom and deck girders by means of large suitably shaped brackets arranged to give a good stress flow at their junctions with both the girders and the bulkheads.

**Hopper Lower Cross Members**

**8514** Cross members are to be fitted within the hopper space in line with the bottom and side shell transverses and with the bulkheads in the side buoyancy spaces. Cross members need not be fitted at every frame, but their spacing is not to exceed 4,0 m.

Where a box keel is fitted on the centreline, webs are to be fitted within the box keel to ensure continuity of strength across the vessel in way of the hopper cross member. See 8519.

**8515** The upper edge of the cross members should in, general, be at a height of not less than  $D/4$  above the keel in vessels with the number 100 in their character of classification. The lower edge should be as low as practicable allowing for hopper doors, suction passages, etc.

**8516** Cross members may be fabricated from flat plate suitably stiffened or may take the form of a hollow box, generally of triangular cross-section.

**8517** The scantlings of box-type cross members should be determined from the requirements for hopper bulkheads where applicable.

**8518** Where flat plate cross members are fitted, the thickness of the web is not to be less than:—

$0,7B + 3$  mm, or 8,5 mm, whichever is the greater.

The cross-sectional area of the cross member web after deducting access openings, lightening holes, etc., is not to be less than  $6 h_w s$  cm<sup>2</sup>.

where  $h_w$  = height, in metres, of the uppermost hopper overflow weir above the keel,

$s$  = spacing of the cross member webs, in metres.

The upper edge of the cross member is to be stiffened by means of a tube having an outside diameter not less than  $30 S$  mm and a thickness equal to the minimum required cross tie web thickness, or by an equivalent flange or structure,

where  $S$  = span, in metres, of the upper edge of the cross member (to the centreline box girder if fitted).

The lower edge of the cross member is also to be suitably stiffened.

The cross member web is to be fitted with stiffeners, spaced not more than  $80 t$  mm apart having a modulus of not less than  $0,04 s S^2$  cm<sup>3</sup>,

where  $t$  = actual thickness of the cross member web, in mm,

$s$  = spacing of stiffeners, in mm,

$S$  = span of stiffeners, in metres.

**8519** The webs required within centreline watertight box keels may have a thickness 3,5 mm less than that required for the hopper cross members with which they are associated, but their minimum thickness is not to be less than 6,5 mm.

**Hopper Upper Cross Members**

**8520** Cross members spanning hopper spaces at or above deck level are to be designed on the basis of actual loads carried, including dynamic factors if applicable, and 60 per cent end fixity. Total stress  $f_c$  is not to exceed 117,7 N/mm<sup>2</sup> (12 kgf/mm<sup>2</sup>), bending stress  $f_b$  is not to exceed 74,5 N/mm<sup>2</sup> (7,6 kgf/mm<sup>2</sup>), shear stress  $f_s$  is not to exceed 68,6 N/mm<sup>2</sup> (7 kgf/mm<sup>2</sup>), and  $f_c = \sqrt{f_b^2 + 3f_s^2}$ .

They should, in general, be connected to the centreline box keel by one or more pillars, where such a keel is fitted.

**Pillars within Hoppers**

**8521** Pillars are generally to comply with the requirements of D 14, account being taken of the maximum forces that can be applied by rams or other gear fitted for the purpose of activating hopper doors or valves.

**Continuous Coamings**

**8522** Continuous coamings are to have a plate thickness of not less than 8,5 mm. A minimum thickness of 10 mm is recommended for hopper coamings on grab dredgers.

**8523** Where the height of the coaming exceeds  $80 t$  the plating is to be stiffened by one or more horizontal members so spaced that the width of the upper panel of plating does not exceed  $65 t$  and the width(s) of the lower panel(s) do(es) not exceed  $80 t$ .

Where the coaming is stiffened with flat bar members, these members are to have a depth not less than  $40 l_e$  mm, a thickness not less than 0,05 times their depth, or 8,5 mm, whichever is the greater, and are to have a minimum moment of inertia  $I = 2 l_e^3 A$  cm<sup>4</sup>.



Where stiffeners other than flat bars are used, they are to have at least the same minimum thickness and inertia as is required for flat bars.

**8524** The upper edge of the coaming is to be stiffened by a fabricated flange, box girder or equivalent structure having a width not less than  $50 l_e$  mm, and an inertia not less than  $I = 2,85 l_e^2 A_1$  cm<sup>4</sup>.

The thickness and/or attachments of the stiffening member are to be such as to minimize any likelihood of local instability under compression loading.

**8525** The coamings are to be supported by substantial brackets spaced generally not more than 3 m apart when the coamings have a height of more than 600 mm, nor more than 2,5 m when the coamings have a height of more than 1,0 m, but on longitudinally framed ships the brackets should be arranged in way of each deck transverse. Additional brackets may be required in way of the ends of hopper upper cross ties especially those which themselves support hopper door operating rams or similar equipment.

**8526** The ends of continuous coamings are to be well scarfed into the ship's structure at the ends of the hopper or sand hold. Unless longitudinal deckhouse bulkheads are fitted in this area, the coamings are to be extended beyond the end of the hopper or sand hold opening for a distance of at least one frame space or 1,5 times the coaming height, whichever is the greater.

## Section 86

### SIDE FRAMING

#### Longitudinal Side Framing

**8601** The minimum moduli of side longitudinals are to be as required by D 6 for ships classed 100A1 or 100A1 restricted service, but may be reduced by 5 per cent on ships classed A1 protected waters service.

**8602** The spacing of transverses and web frames supporting side longitudinals may, on request, be permitted to be increased up to a maximum of 4 m.

**8603** The modulus of web frames and transverses supporting side longitudinals amidships on hopper dredgers and sand carriers classed 100A1 restricted service may be 5 per cent less than that required by D 6.

On all ships classed A1 protected waters service, the modulus of web frames and transverses may be 10 per cent less than that required by D 6.

**D 8524 - D 8702**

**8604** Transverses and web frames supporting side longitudinals abreast of hoppers and sand holds are to have an inertia of not less than:—

$$I = 2,5 S \left( \frac{l}{y} \right) \text{ cm}^4$$

where  $S$  = span of the member, in metres, measured between span points.

**8605** For wash bulkheads fitted in lieu of web frames abreast hoppers and sand holds, see D 8511.

**8606** The end connections of side transverses and web frames to deck and bottom transverses abreast of hoppers or sand holds are to be arranged to prevent shear buckling of the members' webs. In general, stiffeners are to be arranged such that web panels in way of the junction do not exceed  $80 t \times 60 t$  in size, where  $t$  is the actual web plate thickness.

#### Transverse Side Framing

**8607** The modulus of side frames amidships may be reduced by 8 per cent of ships classed A1 protected waters service.

**8608** For arrangements in way of fenders, see D 9012.

#### Panting Arrangements

**8609** The requirements of D 11 need not be complied with on ships classed A1 protected waters service.

## Section 87

### BULWARKS, FREEING PORTS, SCUPPERS AND SANITARY DISCHARGES AND SIDE SCUTTLES

**8701** In general, bulwarks are not to be fitted in way of open hoppers. In no case are bulwarks to be fitted in way of open hoppers where the hopper weirs discharge on to the deck instead of into enclosed overflow trunks.

Bulwarks are not to be fitted in way of open hatches on sand carriers.

If bulwarks are fitted, freeing ports are to be provided throughout their length and of sufficient size to permit the immediate overboard discharge of any spoil that may spill out of the hopper in the event of the dredger rolling excessively.

#### Hopper Weirs and Overflows

**8702** All hoppers and the holds of sand carriers are to be arranged to permit the safe and efficient overboard discharge of excess water in all weather conditions in which the ship is classed to operate.



In hopper dredgers, sand carriers and in all ships classed 100A1 without restriction, the hold and hopper overflows are to be arranged via enclosed overflow trunks so designed as to keep the decks of the ship clear of spoil and water.

**8703** Where a hopper dredger or sand carrier operates at the maximum draught that could be assigned in accordance with the International Load Line Convention 1966, the overflow arrangements fitted should ensure that when the hopper of the dredger or the hold of the sand carrier is loaded this draught is not exceeded. In this condition, the trim and bending moments should be acceptable.

Where a hopper dredger having releasing arrangements for cargo dumping, e.g. bottom doors, etc., is permitted by an Administration to be assigned a freeboard less than that which could be assigned by the International Load Line Convention 1966, the Society should be satisfied with regard to the following:—

- (a) The structural strength and bending moments are acceptable for the deeper draught indicated.
- (b) The dredger operates in a zone of operation and such conditions of weather as are considered appropriate.

Adequate arrangements are to be fitted so as to prevent overloading under any condition of loading having due regard to trim.

The size and position of the overflows should be confirmed by a loading trial, which should be carried out when the hopper or sand hold is loaded with dredgings of the same density as is likely to be loaded in service.

**8704** The cutting of overflow discharge trunk openings in the sheer strake is to be avoided whenever practicable.

Hopper overflow discharge trunk openings are not to be cut within 800 mm of the upper edge of the sheer strake. They are to have corner radii of not less than 150 mm and suitable compensation is to be arranged. In no case is a discharge trunk to pierce the sheer strake in way of discontinuities such as breaks of superstructure.

#### Protection of Pipes and Valves

**8705** In all areas where damage might be likely, all side scuttles, scuppers and discharges including their valves, controls and indicators are to be well protected. Consideration is to be given to the likelihood of impact damage to scuttles and discharges due to barges coming alongside, and to scuppers becoming blocked by sand or other spoil which may spill onto the decks or other areas being drained.

**8706** Consideration will be given to requests for relaxation of requirements relating to scuttles, scuppers and discharges on ships classed A1 protected waters service.

#### Section 88

#### WELDING

**8801** The welding in hopper spaces is to be as given in Table D 88.1. The welding in all other areas, including hold spaces in sand carriers, is to be as required by D 32.

**8802** For welding of shell chines, see D 8307.

TABLE D 88.1

HOPPERS	*WELD FACTOR	REMARKS
Bulkhead boundary connections	0,39	At bottom and sides
	0,35	At deck and coamings
Bulkhead stiffeners	0,12	
Girders and web frames to bulkheads	0,21	Generally clear of end brackets
	0,26	In way of end brackets
Girder webs to face bars	0,12	
Girder web stiffeners to web	0,12	
Girders to girder brackets	0,26	Generally continuous
Stiffeners to end brackets	—	See Table D 32.1, Note 6
Beam webs to face bars	0,12	Continuous
Cross members to bulkheads and keel	0,39	Continuous
Pillar and connections	0,35	
Hopper door hinges	0,44	Full penetration generally required

\*See Notes to Table D 32.1



Section 89**EQUIPMENT****General**

**8901** The regulations governing the assignment of the figure 1 for equipment are contained in B 203.

**8902** For ships engaged in special services, an equipment number differing from the requirements of Table D 34.1 may be approved by the Committee if considered suitable for the particular service on which the ship is to be engaged. *See also* 8907.

**8903** When determining the value of the equipment numeral  $\Delta$  = moulded displacement, in tonnes, to the summer load waterline, i.e. at draught  $d$ . *See also* D 8104.

**8904** On ships classed 100A1 restricted service, the weight of the bower anchors and the length and diameter of the bower anchor chain cables may be derived from Table D 34.1, using the values two grades below the calculated equipment number.

**8905** On ships classed A1 protected waters service, the weight of the bower anchors and the diameter of the bower anchor chain cables may be derived from Table D 34.1, using the value for an equipment number one-half of the ship's calculated equipment number. Two anchors are to be carried on powered ships and one anchor is to be carried on unpowered (but manned) ships. The length of each of the bower anchor chain cables is to be not less than 2L m or ten times the maximum depth at which the ship is designed to dredge, whichever is the greater, but need not exceed the length required for ordinary cargo ships with the same anchor weight.

**8906** On ships classed A1 protected waters service, wire rope may be substituted for the chain cable of the bower anchors. This wire rope is to have a breaking strength not less than 1.5 times that required for the chain cable. It should normally consist of six strands of an "equal lay" construction over an independent wire rope core. ("Cross lay" strands over a fibre core will not generally be acceptable.)

**Unmanned Barges**

**8907** On unmanned barges, only one anchor need be carried.

The length of anchor cable is not to be less than 40 m or 2L m, whichever is the greater, on each anchor fitted.

**NOTE.** In general, if desired, all anchors and cables may be omitted, in which case the number 1 will be omitted from the character of classification.

**Working and Stowing Anchors and Cables**

**8908** On unpowered ships, the windlass may be hand operated.

**8909** When wire rope is used instead of chain for the anchor cable, it is to be stored on a suitably designed drum or reel.

**8910** Fairleads intended for use with wire rope cable are to be designed to minimize wear and to avoid kinking or other similar damage occurring to the rope. Fairleads should, in general, be fitted with rollers having a diameter not less than eleven times the diameter of the anchor cable, but a ratio of not less than 15.7 to 1 is recommended.

Section 90**MISCELLANEOUS ITEMS****Watertight Bulkheads**

**9001** The number of watertight bulkheads is to be not less than as required for dry cargo ships. Their positioning should be such that one extends the full width of the ship at each end of the hopper spaces. *See also* D 8512.

**9002** The Committee will be prepared to consider proposals to dispense with one or more of the watertight bulkheads in that part of the ship in way of hoppers. In particular, watertight bulkheads need not be fitted within hoppers and an increased spacing of bulkheads in the spaces abreast of hoppers and sand holds will generally be accepted provided that:—

- (a) suitable structural compensation is arranged, and
- (b) the stability is checked in the damaged condition.

**Exposed Casings**

**9003** Exposed casings on ships classed A1 protected waters service are to have scantlings as required for deck-houses on dry cargo ships classed 100A1.

**Dredging Machinery Seats**

**9004** The seats supporting the main dredging machinery are to be at least as substantial as those required for the main propulsion machinery for dry cargo ships.

Continuity between the longitudinal and transverse members of main engine seats and the ship's bottom structure is to be arranged where practicable.



**9005** Where floors are cut away below dredging pumps, they should be fitted with face bars, and special care is to be taken to minimize stress raising details and to ensure good workmanship.

**9006** Where  $d_m$  equals or exceeds the draught corresponding to B-60 freeboards on ships classed 100A1, direct access is not permitted to the machinery spaces (including dredging pump rooms) from the freeboard deck.

Doors may be fitted in exposed casing bulkheads provided they lead to a space which is of equivalent strength to the casing and is separated from the machinery space by a second weathertight door.

#### Rudders and Sternframes

**9007** Where bucket dredgers are arranged with bucket ladders at their stern, the ship's rudders are to be kept well clear of the buckets to minimize the likelihood of the rudders being damaged by large items which may be dredged up.

**9008** The solepiece on ships classed A1 protected waters service is to be so designed that:—

- (a) The transverse bending stress does not exceed  $78,5 \text{ N/mm}^2$  ( $8 \text{ kgf/m}^2$ ) assuming that the mean pressure acting on the rudder is  $98 (V+3)^2 \text{ N/mm}^2$  ( $10 (V+3)^2 \text{ kgf/m}^2$ ), where  $V$  is the maximum service speed, in knots, with the ship in the loaded condition.
- (b) The cross-sectional area is not less than  $18 \text{ cm}^2$ .
- (c) The thickness is not less than two-thirds of its width at any point.

**9009** On ships classed A1 protected waters service, the rudder stock diameter may be 84 per cent of that required for ships classed 100A1.

On non-self-propelled ships,  $k$  is to be taken as 0,226.

#### Ladder Wells

**9010** Where ladder wells are incorporated into a dredger, hopper dredger, or sand carrier, such that the length of the well exceeds 1,5 times the width of the deck remaining on each side of the well, the portions of the vessel on each side of the well are to be adequately cross connected in the region of their free ends, unless the design of the ship renders this impracticable, in which case alternative arrangements are to be made to avoid high stress concentrations at the inboard end of the well.

#### Dredging Gear

**9011** Where masts or derrick posts support dredging gear which will be subjected to vibration or other dynamic loads in addition to its true weight, then this must be taken into account in the calculations. The dynamic multiplier should be taken between two and three according to the type of machinery and gear used.

#### Fenders

**9012** Dredgers designed to work in conjunction with hopper barges are to be fitted with permanent rubbing strakes or fenders extending down to their lowest normal operating waterline. On transversely framed vessels it is recommended that the side structure in way of the lower edge of the fender be reinforced by a stringer and/or cross ties. It is recommended that, when wooden fenders are fitted to dredgers operating in tropical sea water, the fenders be cut just above the deepest working waterline and a gap left sufficient to prevent water soaking up into the fenders.





## Chapter E

### PUMPING AND PIPING

#### Section 1

##### PLANS

101 The following plans are to be submitted for consideration:—

General pumping arrangements, including air and sounding pipes and any cross flooding pipes and fittings. (Ship-builder's plan).

Pumping arrangements at the forward and after ends of oil tankers and drainage of cofferdams and pump rooms.

General arrangement of cargo piping in tanks and on deck of oil tankers.

Piping arrangements for cargo oil (F.P. 60°C or above, closed cup test).

Bilge, ballast and oil fuel pumping arrangements in the machinery space, including the capacities of the pumps on bilge service. In the case of passenger ships the criterion numeral, as defined in the *International Convention for the Safety of Life at Sea, 1960* is to be stated together with the number of flooded compartments which the ship is required to withstand under damage conditions.

Arrangement of oil fuel pipes and fittings at settling and service tanks.

Arrangements of oil fuel piping in connection with oil burning installations and oil fired galleys.

Oil fuel and cargo oil overflow systems, where these are fitted.

Arrangement of boiler feed system.

Arrangement of compressed air systems for main and auxiliary essential services.

Arrangements of lubricating oil and cooling water systems for main and auxiliary essential services, oil fuel settling, service and other oil fuel tanks not forming part of the ship's structure.

Arrangements and dimensions of all steam pipes where the design pressure exceeds 1,72 N/mm<sup>2</sup> (17,5 kgf/cm<sup>2</sup>) and the outside diameter exceeds 76,1 mm with details of flanges, bolts and weld attachments, and particulars of the material of pipes, flanges, bolts and electrodes.

Above plans of piping are to be diagrammatic.

NOTE. Plans additional to the above should not be submitted unless the arrangements are of a novel or special character affecting classification.

See Chapter L for Control Engineering Equipment.

See Chapter R(B) for *Provisional Rules for Plastic Pipes*.

See Chapter R(D) for *Guidance Notes on Metal Pipes for Water Services*.

#### Section 2

##### GENERAL

201 In power driven ships the pumping arrangements according to the division of compartments, rise of floor and other conditions are to be as detailed in these Rules which apply to passenger ships, cargo and other ships except where otherwise stated.



202 While the arrangements satisfy the requirements of the *International Convention for the Safety of Life at Sea, 1960*, attention should be given to any relevant statutory requirements of the National Authority of the country in which the ship is to be registered.

203 The Committee will be prepared to give consideration to special cases or to arrangements which are fully equivalent to those required by these Rules. Consideration will also be given to the pumping arrangements of small ships and ships to be assigned class notations for restricted or special services.

For pumping arrangements of non-self-propelled ships, see E 10.

### BILGE AND BALLAST

204 All ships are to be provided with efficient pumping plant having the suctions and means for drainage so arranged that any water within any compartment of the ship, or any watertight section of any compartment, can be pumped out through at least one suction when the ship is on an even keel and is either upright or has a list of not more than 5 degrees. For this purpose wing suctions will generally be necessary, except in short, narrow compartments where one suction can provide effective drainage under the above conditions.

In passenger ships the pumping plant is to be capable of draining any watertight compartment under all practical conditions after a casualty, whether the ship is upright or listed.

#### Hold Drainage

205 In ships having only one hold, and this over 33,5 m in length, bilge suctions are to be fitted in suitable positions in the after half-length, also in the forward half-length of the hold.

206 Where close ceiling or continuous gusset plates are fitted over the bilges, arrangements are to be made whereby water in a hold compartment may find its way to the suction pipes.

207 Where the inner bottom plating extends to the ship's side, the bilge suctions are to be led to wells placed at the wings. If the tank top plating has inverse camber, a well is also to be fitted at the centreline, but in the case of trawlers and fishing vessels, a single well fitted at the centre may be accepted.

Bilge wells are to be formed of steel plates and are not to be less than 0,17 m<sup>3</sup> capacity, except in trawlers and fishing vessels where the capacity is not to be less than

0,11 m<sup>3</sup>. In small compartments, steel bilge hats of reasonable capacity may be fitted.

In passenger ships wells in double bottom tanks are not to extend downwards more than necessary; the depth of the well is in no case to be more than the depth less 460 mm of the double bottom at the centreline, nor shall the well extend below the horizontal plane referred to in D 909.

Where access manholes to bilge wells are necessary, they are to be fitted as near to the suction strums as practicable.

208 Access to the bilge suction strum of a hold well should not be obtained by means of a manhole in the machinery space watertight bulkheads or tank top plating in the machinery space or tunnel if this can be avoided.

Where, however, this arrangement is necessary, the watertight manhole cover should be of hinged type and an instruction plate, in raised letters, should be affixed in a well lighted position, to the effect that this door must be kept shut, except when access is required. In passenger ships these arrangements are not permissible.

209 The intactness of the machinery space bulkheads, and of tunnel plating which is required to be of watertight construction, is not to be impaired by the fitting of scuppers discharging to machinery space or tunnels from adjacent compartments which are situated below the bulkhead deck.

These scuppers may, however, be led into a strongly constructed scupper drain tank situated in the machinery space or tunnel but closed to these spaces and drained by means of a suction of appropriate size led from the main bilge line through a screw-down non-return valve.

The tank air pipe is to be led to above the bulkhead deck and provision is to be made for ascertaining the level of water in the tank.

Where one tank is used for the drainage of several watertight compartments, the scupper pipes are to be provided with screw-down non-return valves.

210 Steering gear compartments or other small enclosed spaces situated above the after peak tank are to be provided with suitable means of drainage either by hand or power pump bilge suctions.

If, however, these compartments are adequately isolated from the adjacent 'tween decks, they may be drained by scuppers not less than 38 mm bore, discharging to the tunnel and fitted with self-closing cocks situated in well lighted and visible positions. These arrangements are not applicable to passenger ships unless specially approved in relation to sub-division considerations.



In the case of trawlers and fishing vessels, steering gear compartments or other small enclosed spaces situated above the after peak tank, and water-tight cabin flats which overhang the thrust recess, are to be provided with suitable means of drainage, which may be either hand or power pump suction or by scuppers not less than 38 mm bore draining to the engine room through self-closing cocks fitted in readily accessible positions in the engine room.

#### Drainage from Refrigerated Cargo Spaces

211 Provision is to be made for the continuous drainage of the inside of all insulated chambers and cooler trays.

212 Drains which are led from lower holds and cooler trays situated on the tank top are to be fitted with liquid sealed non-return bilge traps.

Drains from 'tween deck chambers and from cooler trays which are situated well above the tank top are also to be fitted with liquid sealed traps, but the non-return valves may be omitted if desired. For insulation of scupper pipes, *see* E 418.

213 Where drains from separate chambers join a common main, the branch pipes are each to be provided with a liquid sealed trap.

214 The liquid sealed traps are to be of adequate depth, and arrangements are to be made for ready access to the traps for cleaning and refilling with brine.

215 Sluices, scuppers or drain pipes which would permit drainage from compartments outside the insulated chambers into the bilges of the latter are not to be fitted.

216 Screwed plugs or other means for blanking off scuppers draining insulating chambers and cooler trays are not to be fitted.

If, however, it is specially desired by the Owners to provide means for temporarily closing these scuppers, they may be fitted with shut-off valves controlled from readily accessible positions on a deck above the load waterline.

#### Machinery Space—Bilge Drainage

217 The bilge drainage arrangements in the machinery space are to be such that any water which may enter this compartment can be pumped out through at least two bilge suction when the ship is on an even keel and is either upright or has a list of not more than 5 degrees. One of these suction is to be a branch bilge suction, i.e. a suction connected to the main bilge line, and the other is to be led direct from an independent power pump. Examples of the necessary arrangements are detailed in 218 to 220.

In passenger ships the drainage arrangements are to be such that machinery spaces can be pumped out under all practical conditions after a casualty whether the ship is upright or listed.

Where it is intended that the engine and/or boiler rooms will not be continuously manned at sea, an approved bilge level alarm system is to be provided in these spaces to give warning of flooding, *see* L 207. The alarm system is to operate audible and visible signals at the station from which the machinery is controlled which should be in direct communication with the bridge. When control is being effected from the bridge only, the alarms must operate in the engine room control station and in the Engineer Officers' accommodation.

218 Where the double bottom extends the full length of the machinery space and forms bilges at the wings, it will be necessary to provide one branch and one direct bilge suction at each side.

219 Where the double bottom plating extends the full length and breadth of the compartment, one branch bilge suction and one direct bilge suction are to be led to each of two bilge wells, situated one at each side. The capacity of each bilge well is not to be less than 0,17 m<sup>3</sup> with the exception of trawlers and fishing vessels where the capacity is not to be less than 0,11 m<sup>3</sup>.

In passenger ships the depth of bilge wells is to comply with the requirements of 207.

220 Where there is no double bottom and the rise of floor is not less than 5 degrees, one branch and one direct bilge suction are to be led to accessible positions as near the centreline as practicable.

In ships where the rise of floor is less than 5 degrees and in all passenger ships additional bilge suction are to be provided at the wings.

221 Additional bilge suction may be required for the drainage of depressions in the tank top formed by crank pits, or other recesses, by tank tops having inverse camber or by discontinuity of the double bottom.

222 In ships in which the propelling machinery is situated at the after end of the ship, it will generally be necessary for bilge suction to be fitted in the forward wings as well as the after end of the machinery space, but each case will be dealt with according to the size and structural arrangements of the compartment.

223 In ships propelled by electrical machinery, special means are to be provided to prevent the accumulation of bilge water under the main propulsion generators and motors.



224 Where the machinery space is divided by watertight bulkheads to separate the boiler room(s) or auxiliary engine room(s) from the main engine room, the number and position of the branch bilge suction in the boiler room(s) and auxiliary engine room(s) are to be the same as for cargo holds.

In addition to the branch bilge suction an independent power pump direct bilge suction is to be fitted in each compartment. Similar provision is to be made in separate motor rooms of electrically propelled ships.

225 In passenger ships each independent bilge pump is to have a direct bilge suction from the space in which it is situated, but not more than two such suction are required in any one space. Where two or more such suction are provided there is to be at least one suction on each side of the space.

#### Machinery Space—Emergency Bilge Drainage

226 In steamers, the main circulating water pump to each main engine is to be fitted with an emergency bilge suction, i.e. "bilge injection", which is to be additional to the bilge suction detailed in 217 to 225. This suction, which is to have a diameter of at least two-thirds that of the pump suction, is to be led to a suitable low level in the machinery space and is to be fitted with a screw-down non-return valve having the spindle so extended that the hand-wheel is not less than 460 mm above the bottom platform.

If two pumps are provided for one engine, each capable of supplying sufficient cooling water for normal power, only one pump need be fitted with an emergency bilge suction.

Where main circulating water pumps are not suitable for bilge pumping duties, alternative arrangements may be submitted for consideration.

227 In motorships, the emergency bilge suction is to be led to the main cooling water pump or to the main cooling water suction line. The suction is to be of the same size as the suction branch of the cooling water pump and the valve nameplate is to be marked "For emergency use only".

Alternatively, the emergency bilge suction may be led to the largest available power pump which is not fitted with a direct bilge suction and is to be of the same size as the suction branch of the pump. This pump is to have a capacity greater than that required for a bilge pump, and if it is of the self-priming type the direct bilge suction on the same side of the ship as the emergency suction may be omitted, except in passenger ships.

This emergency bilge suction is additional to the bilge suction detailed in 217 to 225 and is to comply with the requirements of 226 as regards location and valve arrangements.

#### Tunnel Drainage

228 The tunnel well is to be drained by a suction from the main bilge line. In all ships including passenger ships this well may extend to the outer bottom.

229 Where the tank top in the tunnel slopes down from aft to forward, a bilge suction is to be provided at the forward end of the tunnel, in addition to the tunnel well suction required by 228.

#### Sizes of Bilge Suction Pipes

230 The diameters of bilge suction pipes are not to be less than required by the following formulæ, to the nearest 5 mm:—

##### MAIN BILGE LINE

$$d_m = \sqrt{2,78 L (B + D)} + 26 \text{ mm} \quad (1)$$

In no case is the diameter of the main bilge line to be less than required for any branch bilge suction.

##### BRANCH BILGE SUCTIONS TO CARGO AND MACHINERY SPACES

$$d_b = \sqrt{4,63 C (B + D)} + 26 \text{ mm} \quad (2)$$

where  $d_m$  = internal diameter of main bilge line, in mm,

$d_b$  = internal diameter of branch bilge suction, in mm,

$L$  = Rule length of ship, in metres,

$B$  = Rule breadth of ship, in metres,

$D$  = moulded depth to bulkhead deck, in metres,

$C$  = length of compartment, in metres.

No bilge suction pipe is, however, to be less than 50 mm bore.

##### DIRECT BILGE SUCTIONS, OTHER THAN EMERGENCY SUCTIONS

231 The direct bilge suction in the main engine room and the direct bilge suction in large separate boiler rooms, motor rooms of electrically propelled ships and auxiliary engine rooms are not to be of a diameter less than required for the main bilge line.

Where the separate machinery spaces are of small dimensions, the sizes of the direct bilge suction to these spaces will be specially considered.

For sizes of emergency bilge suction, see 226 and 227.

232 In oil tankers and similar ships where the engine room pumps do not deal with bilge drainage outside the machinery space, the diameter of the main bilge



line may be less than required by formula 230 (1), provided the cross-sectional area is not less than twice that required for the branch bilge suction in the machinery space.

233 The area of each branch pipe connecting the bilge main to a bilge distribution chest is not to be less than the sum of the areas required by the Rules for the two largest branch bilge suction pipes connected to that chest, but need not be greater than that required for the main bilge line.

234 The bilge suction pipe to the tunnel well is not to be less than 65 mm bore, except in ships not exceeding 61 m in length, in which case it may be 50 mm bore.

#### Bilge and General Service Pumps

235 For ships other than passenger ships at least two power bilge pumping units are to be provided in the machinery space. In ships of 91,5 m in length and under, one of these units may be worked from the main engines and the other is to be independently driven. In larger ships both units are to be independently driven.

Each of these units is to be connected to the main bilge line and is to be capable of giving a speed of water through the Rule size of bilge of not less than 122 m/minute under ordinary working conditions, but where one unit is of slightly less than this capacity, the deficiency may be made good by an excess capacity of the other unit.

#### 236 TABLE OF CAPACITIES

TABLE E 2.1

BORE OF BILGE PIPE	CAPACITY OF EACH PUMP- ING UNIT	BORE OF BILGE PIPE	CAPACITY OF EACH PUMP- ING UNIT
mm	m <sup>3</sup> /hour	mm	m <sup>3</sup> /hour
51	15	133	103
57	19	140	113
63,5	23	146	124
70	28	152	135
76	34	159	146
82,5	40	165	158
89	46	171	171
95	53	178	183
102	60	184	197
108	68	190	210
114	76	197	224
121	84	203	239
127	93	209	254

237 Each unit may consist of one or more pumps connected to the main bilge line, provided their combined capacity is adequate.

238 In ships other than passenger ships a bilge ejector in combination with a high pressure sea water pump may be accepted as a substitute for an independent bilge pump required by 235.

239 For passenger ships at least three power bilge pumps are to be provided, one of which may be operated from the main engines. Where the criterion numeral is 30 or more, one additional independent power pump is to be provided. A main engine driven pump may be replaced by an independent pump. Each pump is to be connected to the main bilge line and is to be capable of giving a speed of water through the Rule size of main bilge pipe of not less than 122 m/minute.

For location of pumps, see 256.

#### Self-priming Pumps

240 All power pumps which are essential for bilge services are to be of self-priming type, unless an approved central priming system is provided for these pumps. Details of this system are to be submitted.

Cooling water pumps having bilge ejection connections need not be of self-priming type.

#### Pump Connections

241 The connections at the bilge pumps are to be such that one unit may continue in operation when the other unit is being opened up for overhaul.

242 Pumps required for essential services are not to be connected to a common suction or discharge chest or pipe unless the arrangements are such that the working of any of the pumps so connected is unaffected by the other pumps being in operation at the same time.

#### Direct Bilge Suctions

243 The direct bilge suction in the machinery space(s) are to be led to independent power pump(s), and the arrangements are to be such that these direct suction can be used independently of the main bilge line suction.

#### Main Bilge Line Suctions

244 Suctions from the main bilge line, i.e. branch bilge suction, are to be arranged to draw water from any hold or machinery compartment of the ship, excepting small spaces such as those mentioned in 262, where manual pump suction are accepted, and are to be of not less size than required by formula 230 (2). For special arrangements for oil tankers, see E 1135 to E 1140.



**Pipe Systems and their Fittings**

**245** The arrangement of valves, cocks and their connections is to be such as to prevent the possibility of one watertight compartment being placed in communication with another, or of dry cargo spaces, machinery spaces or other dry compartments being placed in communication with the sea or with tanks.

To effect this requirement, the bilge connections to any pump having also suction from the sea and from tanks should be made either by means of non-return valves or cocks which cannot permit communication between the bilges and the sea or compartments in use as tanks.

**246** Screw-down non-return valves are to be provided in the following fittings:—

Bilge valve distribution chests;

Bilge suction hose connections, whether fitted direct to the pump or on the main bilge line;

Direct bilge suction and bilge pump connections to main bilge line.

**247** Bilge pipes which are required for draining cargo or machinery spaces are to be entirely distinct from sea inlet pipes or from pipes which may be used for filling or emptying spaces where water or oil is carried. This does not, however, exclude a bilge ejection connection, a connecting pipe from a pump to its suction valve chest, or a deep tank suction pipe suitably connected through a change-over device to either a bilge, ballast or oil line.

**248** Suctions for bilge drainage in machinery spaces and tunnels, other than emergency suction, are to be led from easily accessible mud boxes fitted with straight tail pipes to the bilges and having covers secured in such a manner as to permit their being expeditiously opened or closed. Strum boxes are not to be fitted to the lower ends of these tail pipes.

**249** The open ends of bilge suction in holds and other compartments outside machinery spaces and tunnels, are to be enclosed in strum boxes having perforations not more than 10 mm diameter, whose combined area is not less than twice that required for the suction pipe. The boxes are to be so constructed that they can be cleared without breaking any joint of the suction pipe.

The distance between the foot of all bilge tail pipes and the bottom of the bilge or well is to be adequate to allow a full flow of water and to facilitate cleaning.

**250** All valves and cocks in connection with bilge, ballast and fresh water suction pipes are to be fitted with legible nameplates, and, unless otherwise specifically mentioned in the Rules, are to be fitted in places where they are at all times readily accessible.

**251** Bilge valves, cocks and mud boxes are to be fitted at, or above, the machinery space and tunnel platforms.

Where it is not practicable to avoid the fittings being situated at the starting platform or in passageways, they may be situated just below the platform, provided readily removable traps or covers are fitted and nameplates indicate the presence of these fittings.

If relief valves are fitted to pumps having sea connections, these valves are to be fitted in readily visible positions above the platform.

**252** Bilge suction pipes are not to be carried through double bottom tanks if it is possible to avoid doing so.

Bilge pipes which pass through these tanks are to be of substantial strength and are to be tested, after fitting, to the same pressure as the tanks through which they pass. In the case of trawlers and fishing vessels, the pipes are to be tested, after fitting, to a pressure of 0,34 N/mm<sup>2</sup> (3,5 kgf/cm<sup>2</sup>).

**253** In way of deep tanks for water ballast, fresh water, oil fuel or cargo oil, bilge pipes should preferably be led through pipe tunnels but, where this is not done, the pipes are to be of steel of heavy gauge with welded joints or heavy flanged joints. The number of joints is to be kept to a minimum.

Expansion bends, not glands, are to be fitted to these pipes within the tanks, and the open ends of the bilge suction pipes in the holds are to be fitted with non-return valves of the special type approved for use in holds, see 266.

Tank piping, other than that of the deep cargo tank pumping system, is not to be situated within deep cargo oil tanks.

The pipes are to be tested, after fitting, to a pressure not less than the maximum head to which the tanks can be subjected, or in the case of trawlers and fishing vessels, to 0,34 N/mm<sup>2</sup> (3,5 kgf/cm<sup>2</sup>).

**254** Bilge, ballast and cooling water suction and discharge pipes are to be permanent pipes made in readily removable lengths with flanged joints, except as mentioned in 253, and are to be efficiently secured in position to prevent chafing or lateral movement.



Where lack of space prevents the use of normal circular flanges, details of the alternative methods of joining the pipes are to be submitted.

Long or heavy lengths of pipes are to be supported by bearers so that no undue load is carried by the flanged connections of the pumps or fittings to which they are attached.

Pipes for bilge, ballast and cooling water systems are to be made of cast iron, steel, copper or other approved material. Heat sensitive materials such as lead are not to be used.

**255** Suitable provision for expansion is to be made in each range of pipes.

Expansion pieces of an approved type incorporating special quality oil resistant rubber or other suitable synthetic material may be used in cooling water lines in machinery spaces. Where fitted in sea water lines, they are to be provided with guards which will effectively enclose, but not interfere with, the action of the expansion pieces and will reduce to the minimum practicable any flow of water into the machinery spaces in the event of failure of the flexible elements.

Proposals to use such fittings in water lines for other services, including:—

- (a) ballast lines in machinery spaces, duct keels and inside double bottom water ballast tanks,
- (b) bilge lines inside duct keels only,

will be specially considered when plans of the pumping systems are submitted for consideration.

#### **Bilge Drainage and Cross Flooding Arrangements for Passenger Ships in Damaged Condition**

**256** In passenger ships the power bilge pumps are, if practicable, to be placed in separate watertight compartments which will not readily be flooded by the same damage. If the engines and boilers are in two or more watertight compartments, the bilge pumps are to be distributed throughout these compartments so far as possible.

In passenger ships of 91,5 m or more in length or having a criterion numeral of 30 or more, the arrangements are to be such that at least one power pump will be available for use in all ordinary circumstances in which the ship may be flooded at sea. This requirement will be satisfied if:—

- (a) One of the pumps is an emergency pump of a submersible type having a source of power situated above the bulkhead deck, or
- (b) The pumps and their sources of power are so disposed throughout the length of the ship that, under any conditions of flooding which the ship

is required by statutory regulation to withstand, at least one pump in an undamaged compartment will be available.

**257** The bilge main is to be arranged so that no part is situated nearer the side of the ship than  $\frac{B}{5}$  where B is the breadth of the ship.

Where any bilge pump or its pipe connection to the bilge main is situated outboard of the  $\frac{B}{5}$  line then a non-return valve is to be provided in the pipe connection at the junction with the bilge main. The emergency bilge pump and its connections to the bilge main are to be arranged so that they are situated inboard of the  $\frac{B}{5}$  line.

**258** Provision is to be made to prevent the compartment served by any bilge suction pipe being flooded in the event of the pipe being severed, or otherwise damaged by collision or grounding in any other compartment. For this purpose, where the pipe is at any part situated nearer the side of the ship than  $\frac{B}{5}$  or in a duct keel, a non-return valve is to be fitted to the pipe in the compartment containing the open end.

**259** All the distribution boxes, valves and cocks in connection with the bilge pumping arrangements are to be so arranged that, in the event of flooding, one of the bilge pumps may be operative on any compartment. If there is only one system of pipes common to all pumps, the necessary valves or cocks for controlling the bilge suctions must be capable of being operated from above the bulkhead deck. Where in addition to the main bilge pumping system an emergency bilge pumping system is provided, it is to be independent of the main system and so arranged that a pump is capable of operating on any compartment under flooding conditions; in this case only the valves and cocks necessary for the operation of the emergency system need be capable of being operated from above the bulkhead deck.

**260** All valves and cocks mentioned in the foregoing paragraphs which can be operated from above the bulkhead deck are to have their controls at their place of operation clearly marked and provided with means to indicate whether they are open or closed.

**261** Where divided deep tanks or side tanks are provided with cross flooding arrangements to limit the angle of heel after side damage, the arrangements are either to be self acting or controlled from above the bulkhead deck.



**Fore and After Peak Drainage**

**262** Where the peaks are used as tanks, a power pump suction is to be led to each tank, except in the case of small tanks used for the carriage of domestic fresh water, when hand pumps may be used.

In passenger and cargo ships, the collision bulkhead is not to be pierced below the bulkhead deck by more than two pipes. The pipes are to be provided with screw-down valves capable of being operated from an accessible position above the bulkhead deck, the chests being secured to the bulkhead inside the fore peak. Indicators are to be provided to show whether the valves are open or shut.

In the case of trawlers and fishing vessels, where a suction pipe is led from the engine room to the fore peak, either through a hold space or through a tank intended to carry oil fuel, it is to be provided with a screw-down valve capable of being operated from an accessible position on deck, the chest being secured to the collision bulkhead inside the fore peak. An indicator is to be provided to show whether the valve is open or shut.

Where the peaks are not used as tanks and main bilge line suctions are not fitted, drainage of both peaks may be effected by hand pump suctions, provided the suction lift be well within the capacity of the pumps and in no case exceeds 7.3 m.

In the case of trawlers and fishing vessels however, where an additional watertight bulkhead is fitted between the collision bulkhead and the machinery space, the fore peak may be drained by means of a cock secured to the fore peak bulkhead and operated from a readily accessible position on deck, means being provided to show whether the cock is open or shut. Where the additional watertight bulkhead is not fitted, the collision bulkhead is to be kept intact. In the case of the after peak, bilge drainage may be effected by means of a self-closing cock fitted in a well lighted and readily accessible position.

Provision is to be made for the drainage of the chain locker and the watertight flat above the fore peak tank by hand or power pump suction. For drainage of the flat above the after peak, tank, *see* 210.

**Watertight Bulkhead and Tunnel Fittings**

**263** Except for trawlers and fishing vessels as stated in 262, no drain valve or cock is to be fitted to the collision bulkhead.

Drain valves or cocks are not to be fitted to other watertight bulkheads, if alternative means of drainage are practicable.

Where fitted, the valves and cocks are to be at all times readily accessible and are to be capable of being shut off

from positions above the bulkhead deck. Indicators are to be provided to show whether the drains are open or shut. These arrangements are not permissible in passenger ships.

Bilge drain valves or cocks may be used for draining the after accommodation spaces and dry peaks of trawlers and fishing vessels as stated in 262.

For drainage of stern compartments, *see* 210.

**264** Valve chests, cocks, pipes or other fittings attached direct to the plating of tanks, and to bulkheads, flats or tunnels which are required to be of watertight construction, are to be secured by means of studs screwed through the plating or by tap bolts and not by bolts passing through clearance holes.

Alternatively, the studs or the bulkhead piece may be welded to the plating.

**Deep Tanks**

**265** In the case of deep tanks which may be used for either water ballast or dry cargo, provision is to be made for blank flanging the water ballast filling and suction pipes when the tank is being used for the carriage of dry cargo and for blank flanging the bilge suction pipes when the tank is being used for the carriage of water ballast.

Change-over devices may be used for this purpose. For arrangements when oil fuel or cargo oil is carried in deep tanks, *see* E 324.

**Hold Bilge Valves**

**266** Where non-return valves are fitted to the open ends of bilge suction pipes in cargo holds in order to decrease the risk of flooding, they are to be of an approved type which does not offer undue obstruction to the flow of water.

**Ship-side Valves and Fittings (other than those on Scuppers and Sanitary Discharges)**

**267** All sea inlet and overboard discharge pipes are to be fitted with valves or cocks secured direct to the shell plating or to the plating of fabricated steel water boxes attached to the shell plating. These fittings are to be secured by bolts tapped into the plating and fitted with counter-sunk heads or by studs screwed into heavy steel pads fitted to the plating. The stud holes are not to penetrate the plating.

Distance pieces of short rigid construction, and made of approved material as required by 270, may be fitted between the valves and shell plating. Distance pieces of steel may be welded to the shell plating. Details of the welded connections and of fabricated steel water boxes are to be submitted.



Gratings are to be fitted at all openings in the ship's side for sea inlet valves and inlet water boxes. The net area through the gratings is not to be less than twice that of the valves connected to the sea inlets and provision is to be made for clearing the gratings by use of low pressure steam or compressed air. *See* 271.

**268** All suction and discharge valves and cocks secured direct to the shell plating of the ship are to be fitted with spigots passing through the plating, but the spigots on the valves or cocks may be omitted if these fittings are attached to pads or distance pieces which themselves form spigots in way of the shell plating.

Blow-down valves or cocks are also to be fitted with a protection ring through which the spigot is to pass, the ring being on the outside of the shell plating.

Blow-down valves or cocks on the ship's side are to be fitted in accessible positions above the level of the working platform and are to be provided with indicators showing whether they are open or shut. Cock handles are not to be capable of being removed unless the cocks are shut, and if valves are fitted, the hand wheels are to be suitably retained on the spindle.

**269** Sea inlet and overboard discharge valves and cocks are in all cases to be fitted in easily accessible positions and, as far as practicable, are to be readily visible. Indicators are to be provided local to the valves and cocks, showing whether they are open or shut.

Provision is to be made for preventing any discharge of water into lifeboats.

The inlet valve spindles are to extend above the lower platform, and the hand wheels of the main injection and bilge injection valves are not to be situated less than 460 mm above this platform.

**270** All valves and cocks are to be of steel, bronze or other approved ductile material; ordinary cast iron is not acceptable. This requirement applies equally to inlet chests, distance pieces and other sea connections.

Material submitted for approval is to have an elongation not less than 12 per cent on a gauge length of  $5,65\sqrt{S_0}$ , where  $S_0$  is the actual cross-sectional area of the test piece.

All these fittings, if made of steel or other approved material with low corrosion resistance, are to be suitably protected against wastage.

**271** The scantlings of valves and valve stools fitted with steam or compressed air clearing connections are to be suitable for the maximum pressure to which the valves and stools may be subjected.

**272** For sea connections for ships having notation for ice navigation, *see* H 509 to H 511, and H 536 to H 537.

### Miscellaneous Requirements

**273** All pipes situated in cargo spaces, fish holds, chain lockers or other positions where they are liable to mechanical damage are to be efficiently protected. (*See* D 2820, quoted at the end of this Section, and D 2914, quoted at the end of E 4.)

**274** Wash deck pipes and discharge pipes from the pumps to domestic water tanks are not to be led through cargo holds if, as is generally the case, it is practicable to avoid doing so. Any proposed departure from this requirement is to be submitted.

**275** So far as practicable, pipe lines, including exhaust pipes from oil engines, are not to be led in the vicinity of switchboards or other electrical appliances in positions where drip or escape of liquid, gas or steam from joints or fittings may cause damage to the electrical installation.

Where it is not practicable to comply with these requirements, drip trays or shields are to be provided as found necessary.

Short sounding pipes to tanks should not terminate near electrical appliances. *See* E 413.

### Extract from Chapter D for reference

NOTE. For ships under 90 m in length, *see* SD 2811 to SD 2819 in the *Rules for Small Ships*.

### Scuppers and Sanitary Discharges

**D 2811** Scuppers sufficient in number and size to provide effective drainage are to be fitted in all decks.

**D 2812** In ships over 150 m in length, scupper openings are not to be cut in the sheerstrake above deck level within 0,5L amidships, and in no case in way of discontinuities such as breaks of superstructures. *See* D 509.

When scuppers or discharges are cut in the shell or superstructure sides compensation may require to be fitted.

**D 2813** Scuppers and discharges which drain spaces below the freeboard deck or spaces within intact superstructures or deckhouses on the freeboard deck fitted with efficient weathertight doors, may be led to the bilges in the case of scuppers or to suitable sanitary tanks in the case of sanitary pipes. Alternatively, they may be led overboard provided the spaces drained are above the load waterline, and the pipes are fitted with efficient and accessible means of preventing water from passing inboard. *See* 2814.

**D 2814** In general, each separate overboard discharge is to be fitted with a screw-down non-return valve capable of



being operated from a position always accessible and above the freeboard deck. An indicator is to be fitted at the control position showing whether the valve is open or closed.

Where, however, the vertical distance from the summer load waterline to the inboard end of the discharge pipe exceeds 0,01L the discharge may be fitted with two automatic non-return valves without positive means of closing, instead of the screw-down non-return valve, provided the inboard valve is always accessible for examination under service conditions.

Where the vertical distance from the summer load waterline to the inboard end of the discharge pipe exceeds 0,02L, consideration will be given to proposals for fitting a single automatic non-return valve without positive means of closing.

**D 2815** Scuppers and discharge pipes originating at any level, which penetrate the shell either more than 450 mm below the freeboard deck or less than 600 mm above the summer load waterline are to be fitted with an automatic non-return valve at the shell.

This valve, unless required by 2813, may be omitted provided the pipe thickness is not less than:—

$$\frac{\text{Diameter of pipe in mm}}{24} + 6,5 \text{ mm}$$

but need not exceed 12,5 mm, unless a greater thickness is required by 2816.

**D 2816** Scuppers and discharge pipes should not normally pass through fuel oil or cargo oil tanks. Where scuppers and discharge pipes pass, unavoidably, through fuel oil or cargo oil tanks, and are led through the shell within the tanks, the thickness of the piping should be at least the same thickness as Rule shell plating in way derived from D 505 or D 4305, but need not exceed 19 mm.

The pipes should be tested in accordance with D 1934 and D 5205. Piping within the tanks should be adequately supported.

If a non-return valve is required by 2813, this should preferably be fitted as close as possible to the point of entry of the pipe into the tank. If fitted below the freeboard deck the valve should be capable of being controlled from an easily accessible position above the freeboard deck. Local control is also to be arranged, unless the valve is inaccessible. An indicator is to be fitted at the control position showing whether the valve is open or closed.

**D 2817** Scuppers draining weather decks and spaces within superstructures or deckhouses not fitted with efficient weathertight doors to be led overboard.

**D 2818** Plans showing the arrangement of scuppers for draining refrigerated cargo compartments are to be submitted for consideration.

#### Materials for Valves, Fittings and Pipes

**D 2819** All valves required by 2814, and shell fittings where no valves are required, are to be of steel, bronze or other approved ductile material; ordinary cast iron is not acceptable. Material submitted for approval is to have an elongation not less than 12 per cent on a gauge length of  $5,65\sqrt{S_0}$ , where  $S_0$  is the actual cross-sectional area of the test piece.

All these items, if made of steel or other approved material with low corrosion resistance, are to be suitably protected against wastage.

The lengths of pipe attached to the required valves or elbow pieces are to be of galvanized steel of standard steam pipe quality or other equivalent approved material. See also F 706.

#### Protection of Pipes and Valves

**D 2820** In all cargo spaces and other areas where damage might be likely, all scuppers and discharges including their valves, controls and indicators are to be well protected. This protection is to be of steel in bulk cargo spaces or their equivalent, and also in areas where contact with large containers, fork lift trucks or similar items is a possibility.

### Section 3

#### OIL FUEL AND CARGO OILS HAVING A FLASH POINT OF 60°C OR ABOVE (CLOSED CUP TEST)

##### General

**301** In addition to the special requirements detailed in this Section, the requirements of E 2 relating to bilge and ballast are to be complied with in so far as they are applicable to the drainage of tanks, oil bilges and cofferdams.

**302** The flash point (closed cup test) of oil fuel for use in ships classed for unrestricted service is in general not to be less than 60°C. For emergency generator engines a flash point of not less than 43°C is permissible.

Fuels with flash points lower than 60°C may be used in ships intended for service restricted to geographical limits where it can be ensured that the temperature of the machinery and boiler spaces will always be 10degC below the flash point of the fuel. In such cases, safety precautions



and the arrangements for storage and pumping will be specially considered. However, the flash point of the fuel is not to be less than 43°C unless specially approved.

When it is desired to carry a quantity of fuel having a flash point below 43°C for special services, e.g. aviation spirit for use in helicopters, full particulars of the proposed arrangements are to be submitted for special consideration. For the burning of methane gas in methane tankers, see the *Rules for Ships for Liquefied Gases*.

#### Oil Fuel Pumps and Oil Burning Appliances

**303** In every ship where steam for the main propelling engines, or for auxiliary machinery which is required for essential services, is generated by burning oil fuel under pressure, there are to be not less than two oil burning units, each unit comprising a pressure pump, a suction filter, a discharge filter and a heater.

In two unit installations, each unit is to be capable of supplying fuel for generating all the steam required for essential services.

In installations of three or more units, the capacities and arrangements of the units are to be such that all the steam required for essential services can be maintained with any one unit out of action.

**304** Unit pressure pumps for the oil burning system are to be entirely separate from the feed, bilge or ballast systems.

**305** In systems where oil is fed to the burners by gravity, duplex filters are to be fitted in the supply pipeline to the burners and so arranged that one filter can be opened up when the other is in use. Similar or equivalent arrangements are to be provided in the fuel supply lines to main and auxiliary oil engines and gas turbines.

**306** If oil fuel is sprayed by steam, means are to be provided to carry or make up the fresh water used for this purpose.

**307** A starting-up oil fuel unit, including an auxiliary heater and hand pump, or other suitable starting-up device, which does not require power from shore, is to be provided.

Alternatively, where auxiliary machinery requiring compressed air or electric power is used to bring the boiler plant into operation, the arrangements for starting such machinery are to comply with H 611.

**308** All pumps used in connection with oil fuel are to be provided with effective escape valves which are to be in close circuit, i.e. discharging back to the suction side of the pumps.

Escape valves are also to be fitted on the oil side of the heaters, discharging to the pump suction line, to the tray under the unit, or to other approved positions, and are to be adjusted to operate at a pressure of 0,34 N/mm<sup>2</sup> (3,5 kgf/cm<sup>2</sup>) above that of the pump escape valve.

**309** Where a power driven transfer pump is necessary for pumping up the settling tanks in motorships and steamships, a standby pump is to be provided and connected ready for use, or alternatively, emergency connections may be made to one of the unit pumps or to another suitable power driven pump.

#### Oil Pipes and Fittings

**310** Pipes conveying heated oil under pressure are to be of seamless steel or other approved material having flanged couplings and placed in sight above the platform in well lighted parts of the stokehold or engine room.

The flanges are to be machined and the jointing material, which is to be impervious to oil heated to 150°C, is to be the thinnest possible, so that the flanges are practically metal to metal. The scantlings of the pipes and their flanges are to be suitable for at least 1,37 N/mm<sup>2</sup> (14 kgf/cm<sup>2</sup>) working pressure, or the pressure, to which the relief valves are adjusted, whichever is the greater.

The piping system is to be tested after jointing to twice the working pressure.

The thickness of the oil fuel pressure pipes is to be determined from the formulæ contained in E 512 and E 513.

**311** The short joining lengths of pipes to the burners from the control valves at the boiler may have cone unions provided these are of specially robust construction.

Flexible pipes of approved material and design may be used for the burner pipes provided spare lengths, complete with couplings, be carried on board.

A quick-closing master valve is to be fitted to the oil supply to each boiler manifold suitably located so that the valve can be readily operated in an emergency, either directly or by means of remote control, having regard to the machinery arrangements and location of controls.

Provision is to be made by suitable non-return arrangements to prevent oil from spill systems being returned to the burners when the oil supply to these burners has been shut off.

In the case of top-fired boilers, means are to be provided so that, in the event of flame failure, the oil fuel supply to the burners is shut off automatically and audible and visible warning is given. Any proposal to depart from this requirement in the case of small auxiliary top-fired boilers would be the subject of special consideration.



**312** Transfer, suction and other low pressure oil pipes and all pipes passing through oil storage tanks are to be made of cast iron or steel, having flanged joints suitable for a working pressure of not less than  $0,69 \text{ N/mm}^2$  ( $7 \text{ kgf/cm}^2$ ). The flanges are to be machined and the jointing material is to be impervious to oil. Where the pipes are 25 mm bore, or less, they may be of seamless copper or copper alloy excepting those which pass through oil storage tanks. Oil pipes within the engine and boiler spaces are to be fitted where they can be readily inspected and repaired, and after jointing they are to be tested to  $0,34 \text{ N/mm}^2$  ( $3,5 \text{ kgf/cm}^2$ ), or twice the maximum working pressure, whichever is the greater.

#### Valves and Cocks

**313** The valves, cocks and their pipe connections are to be so arranged that oil cannot be admitted into tanks which are not structurally suitable for the carriage of oil or into tanks which can be used for the carriage of fresh water intended for boiler feed or for drinking.

In passenger ships provision is to be made for the transfer of oil fuel from any oil fuel storage or settling tank to any other oil fuel storage or settling tank in the event of fire or damage.

**314** Every oil fuel suction pipe from a double bottom tank is to be fitted with a valve or cock.

**315** Every oil fuel suction pipe from a storage, settling and daily service tank situated above the double bottom and every oil fuel levelling pipe within the boiler room or engine room is to be fitted with a valve or cock secured to the tank. In the case of fore peak tanks, these valves are to be fitted on the tank side of the bulkhead.

In the engine and boiler spaces, such valves and cocks are to be capable of being closed locally and from positions which will always be accessible in the event of fire taking place in these spaces. Instructions for closing the valves or cocks are to be indicated at the valves and cocks and at the remote control positions.

In the case of very small tanks consideration will be given to the omission of remote controls.

**316** Every oil fuel suction pipe which is led into the engine and boiler spaces from a tank situated above the double bottom outside these spaces is to be fitted in the machinery space with a remote controlled valve, except where the valve on the tank is already remote controlled.

**317** All valves and cocks forming part of the oil fuel installation are to be capable of being controlled from readily accessible positions which, in the engine and boiler spaces, are to be above the working platform.

Valves or cocks are to be interposed between the pumps and the suction and discharge pipes, in order that any pump may be shut off for opening up and overhauling.

Oil fuel valves are to be so constructed as to prevent the possibility of any cover being slacked back or loosened when operating the valves. The valves and cocks are to be fitted with legible nameplates.

**318** Where the filling pipes to deep oil tanks are not connected to the tanks near the top, they are to be provided with non-return valves at the tanks or with valves or cocks fitted and controlled as in the case of the outlet valves or cocks on these tanks.

**319** Open drains for removing the water from oil tanks are to be fitted with valves or cocks of self-closing type and suitable provision is to be made for collecting the oily discharge.

#### Oil Fired Galleys

**320** The fuel oil tank is to be located outside the galley and is to be fitted with approved means of filling and venting. The fuel supply to the burners is to be controlled from a position which will always be accessible in the event of a fire occurring in the galley. The galley is to be well ventilated.

When liquefied petroleum gas is used similar provisions are to be made.

#### Filling Arrangements

**321** In passenger ships, the filling station is to be isolated from other spaces and is to be efficiently drained and ventilated. Provision is to be made against over-pressure in the filling pipe lines and any relief valve fitted for this purpose is to discharge to an overflow tank or other safe position.

#### Alternative Carriage of Oil Fuel and Water Ballast

**322** Where it is intended to carry oil fuel and water ballast in the same compartments alternatively, the valves or cocks connecting the suction pipes of these compartments with the ballast pump and those connecting them with the oil fuel transfer pump are to be so arranged that the oil may be pumped from any one compartment by the oil fuel pump at the same time as the ballast pump is being used on any other compartment.

Where settling or service tanks are fitted each having a capacity sufficient to permit 12 hours normal service without replenishment, the above requirement may be dispensed with.



**323** Attention is drawn to the statutory regulations issued by National Authorities in connection with the *International Convention for the Prevention of Pollution of the Sea by Oil*, 1954.

#### Deep Tanks for the Alternative Carriage of Oil, Water Ballast or Dry Cargo

**324** In the case of deep tanks which can be used for the carriage of oil fuel, cargo oil, water ballast or dry cargo, provision is to be made for blank flanging the oil and water ballast filling and suction pipes, also the steam heating coils if retained in place, when the tank is used for dry cargo and for blank flanging the bilge suction pipes when the tanks are used for oil or water ballast.

If the deep tanks are connected to an overflow system the arrangements are to be such that liquid or vapour from other tanks cannot enter the deep tanks when dry cargo is carried in them.

#### Oily Bilge Drainage and Sediment Suctions

**325** Provision is to be made for the drainage of oil gutterways, oil wells and cofferdams. See D 1927 to D 1930, quoted at end of this Section.

#### Fresh Water Piping

**326** Pipes in connection with compartments used for storing boiler feed water are to be separate and distinct from any pipes which may be used for oil or oily water, and are not to be led through tanks which contain oil, nor are oil pipes to be led through boiler feed water tanks.

Similar precautions are necessary when the connections are such that fresh water carried in other tanks can be used as reserve feed water.

#### Service, Settling and other Oil Fuel Tanks

**327** In general, the minimum thickness of the plating of these tanks, when they do not form part of the structure of the ship, is to be 5 mm, but in the case of very small tanks, the minimum thickness may be 3 mm.

For rectangular steel tanks of welded construction the plate thicknesses are to be not less than indicated in Table E 3.1. The stiffeners are to be of approved dimensions.

The dimension given in Table E 3.1 for the breadth of the panel is the maximum distance allowable between continuous lines of support, which may be stiffeners, wash-plates or the boundary plating of the tank.

Where necessary, stiffeners are to be provided and if the length of the stiffener exceeds twice the breadth of the panel, transverse stiffeners are also to be fitted, or, alterna-

TABLE E 3.1

THICK- NESS OF PLATE  mm	HEAD FROM BOTTOM OF TANK TO TOP OF OVERFLOW PIPE in metres				
	2,5	3,0	3,7	4,3	4,9
BREADTH OF PANEL in mm					
5	585	525			
6	725	645	590		
7	860	770	700	650	
8	1000	900	820	750	700
10	1280	1140	1040	960	900

tively, tie bars are to be provided between stiffeners on opposite sides of the tank.

On completion the tanks are to be tested by a head of water equal to the maximum to which the tanks may be subjected but not less than 2,5 m above the crown of the tank.

Tanks in which the oil fuel is heated are to be provided with a suitable thermometer pocket.

#### Water Drainage from Settling Tanks

**328** Settling tanks are to be provided with means for draining water from the bottom of the tanks.

If settling tanks are not provided, the oil fuel bunkers or daily service tanks are to be fitted with water drains, see 319.

#### Ventilation

**329** The spaces in which the oil fuel burning appliances, and the oil fuel settling and service tanks are fitted, are to be well ventilated and easy of access.

#### Boiler Insulation and Air Circulation in Boiler Room

**330** The boilers are to be suitably lagged. The clearance spaces between the boilers and tops of the double bottom tanks and between the boilers and the sides of the storage tanks in which oil fuel or cargo oil is carried, are to be adequate for the free circulation of air necessary to keep the temperature of the stored oil well below its flash point.

**331** Where water tube boilers are installed, there should be a space of at least 760 mm between the tank top and the underside of the pans forming the bottom of the combustion spaces.

**332** Smoke-box doors are to be shielded and well fitting, and the uptake joints made gastight.



Where the surface temperature of the uptakes may exceed 220°C, they are to be efficiently lagged to minimize the risk of fire and to prevent damage by heat. Where lagging covering the uptakes including flanges is oil-absorbing or may permit penetration of oil, the lagging is to be encased in sheet metal or equivalent. In locations where the Surveyor is satisfied that oil impingement could not occur, the lagging need not be encased.

#### Funnel Dampers

**333** Dampers which are capable of completely closing the gas passages are not to be fitted to inner funnels of ships equipped for burning oil fuel only. In ships burning oil or coal alternatively, dampers may be retained if they are provided with a suitable device whereby they may be securely locked in the fully open position.

#### Steam Heating Arrangements

**334** Where steam is used for heating oil fuel, cargo oil or lubricating oil, either in bunkers, tanks, heaters or separators, the exhaust drains are to discharge the condensate into an observation tank in a well lighted and accessible position where it can be readily seen whether or not it is free from oil, *see* E 1142.

**335** The steam heating pipes in contact with oil are to be of iron, steel, approved aluminium alloy or approved copper alloy and are to be tested, after being fitted on board, to twice the maximum pressure to which they can be subjected.

**336** The thickness of steel steam heating pipes is to be determined from the formulæ in E 512 and E 513.

#### Control of Pumps

**337** The power supply to the oil fuel transfer and pressure pumps and to the cargo oil pumps is to be capable of being stopped from a position which will always be accessible in the event of fire taking place in the compartment in which they are situated, as well as from the compartment itself.

#### Precautions against Fire

**338** Settling and daily service oil fuel tanks and oil fuel filters are not to be situated immediately above boilers or other highly heated surfaces.

**339** Oil fuel pressure pipes are to be led, wherever practicable, remote from heated surfaces and electrical appliances, but where this is impracticable, the pipes are

to have a minimum number of joints and are to be led in well lighted and readily visible positions.

**340** The arrangement and location of short sounding pipes to oil tanks are to be in accordance with E 413. For alternative sounding arrangements, *see* E 414.

**341** Water service pipes and hoses are to be fitted in order that the floor plates and tank top or shell plating in way of boilers, oil fuel apparatus or deep storage tanks in the engine and boiler spaces can at any time be flushed with sea water.

**342** So far as is practicable, the use of wood is to be avoided in the engine rooms, boiler rooms and tunnels of ships burning oil fuel.

**343** Drip trays are to be fitted at the furnace mouths to intercept oil escaping from the burners and under all other oil fuel appliances which require to be opened up frequently for cleaning or adjustment. The arrangements are to be such that a burner cannot be withdrawn unless the oil fuel supply to that burner is shut off and that the oil cannot be turned on unless the burner has been correctly coupled to the supply line.

For alternately fired furnaces of boilers using exhaust gases and oil fuel, the exhaust gas inlet pipe is to be provided with an isolating device and interlocking arrangements whereby oil fuel can only be supplied to the burners when the isolating device is closed to the boiler.

#### Separation of Cargo Oils from Oil Fuel

**344** Pipes conveying vegetable oils or similar cargo oils are not to be led through oil fuel tanks, nor are oil fuel pipes to be led through tanks containing these cargo oils. *See* D 1932, quoted at the end of this Section.

#### Refrigerated Cargo Spaces in way of Oil Storage Tanks

**345** The insulation of all oil storage tank tops is to have an air space of 50 mm provided between the underside of the insulation and the tank top plating and the supporting battens are to be arranged to provide free drainage to the bilges. Alternatively, the air space may be omitted, provided successive coatings of an approved oil impervious composition be applied to the upper surface of the tank top plating. The total thickness of the coating required will depend on the construction of the tank, the composition used and the method of application.

**346** Riveted bulkheads of deep tanks intended for the carriage of oil are to be separated from refrigerated compartments by a cofferdam.



Provision is to be made for ventilating the cofferdam, the vents being led to the open air and their outlets being fitted with a wire gauze diaphragm which can be easily removed for renewal.

Where the tank bulkhead is wholly welded, including its boundary connections, the cofferdam may be omitted, provided successive coatings of an approved oil-impervious composition be applied to the refrigerated compartment side of the tank bulkhead. The total thickness of the coating required will depend on the composition used and the method of application.

#### Extracts from Chapter D for reference

NOTE. For ships under 90 m in length, see SD 1930 to SD 1936 in the *Rules for Small Ships*.

#### **Protection and Drainage in Tanks Carrying Oil Fuel or Lubricating Oil**

**D 1927** Compartments carrying oil fuel or lubricating oil are to be separated by cofferdams from those carrying feed water, fresh water or vegetable oil. Lubricating oil compartments are to be similarly separated from those carrying fuel oil. Cofferdams are to be suitably ventilated.

For tanks carrying vegetable and similar oils, see 1932.

**D 1928** Gutterways are to be arranged at the foot of bulkheads in boiler rooms to ensure that leakage shall have free drainage to the wells or limbers.

**D 1929** Drip trays or gutterways with suitable draining arrangements are to be provided for all tanks which do not form part of the hull structure, at pumps, valves and elsewhere where there is a possibility of leakage.

Drip trays are also to be fitted under oiltight decks, except if these are completely welded, when the drip trays need only be fitted over boilers and exhaust pipes.

**D 1930** If cargo is carried in a compartment adjacent to an oil fuel settling tank which may be heated, the compartment side of the bulkhead or deck is to be insulated or equivalent arrangements provided.

#### **Tanks carrying Vegetable and Similar Oils**

**D 1932** Deep or peak tanks carrying vegetable or similar oils are to be separated from those carrying oil fuel, lubricating oil or fresh or feed water by a cofferdam.

Cofferdams are not required between oil fuel double bottom tanks and deep tanks above provided the inner bottom plating is not subjected to a head of oil fuel.

### Section 4

#### **AIR, OVERFLOW AND SOUNDING PIPES**

##### **Air and Overflow Pipes**

**401** Air pipes are to be fitted at the opposite end of the tank to that at which the filling pipes are placed and/or at the highest part of the tank.

Where the tank top is of unusual or irregular profile special consideration will be given to the number and position of the air pipes.

Nameplates are to be affixed to the upper ends of all air pipes.

**402** Air pipes to double bottom tanks, deep tanks extending to the shell plating or tanks which can be run up from the sea are to be led to above the bulkhead deck.

Air pipes to oil fuel and cargo oil tanks, cofferdams and all tanks which can be pumped up are to be led to the open. For height of air pipes above deck, see D 2911 quoted at the end of this Section and SD 2911.

**403** The open ends of air pipes to oil fuel and cargo oil tanks are to be situated where no danger will be incurred from issuing oil or vapour when the tank is being filled and each opening is to be furnished with a wire gauze diaphragm of incorrodible material which can be readily removed for cleaning or renewal.

**404** Air pipes from lubricating oil storage tanks may terminate in the machinery space, provided the open ends are so situated that issuing oil cannot come into contact with electrical equipment or heated surfaces.

**405** The closing appliances fitted to tank air pipes, in accordance with D 2912 and SD 2912, are to be of a type which will prevent excessive pressure coming on the tanks.

Provision is to be made for relieving vacuum when the tanks are being pumped out and for this purpose a hole about 10 mm diameter in the bend of the air pipe or in a suitable position in the closing device will be acceptable.

**406** In the case of all tanks which can be pumped up, either by the ship's pumps or by shore pumps through a filling main, the total cross-sectional area of the air pipes to each tank or of the overflow pipes where an overflow system is provided, is not to be less than 25 per cent greater than the effective area of the respective filling pipes.

Where tanks are fitted with cross flooding connections the air pipes are to be of adequate area for these connections.

Wood plugs and other devices which can be secured closed are not to be fitted at the outlets.



In wire gauze diaphragms at air pipe openings, the area of the clear opening is not to be less than the cross-sectional area required for the pipe.

Air pipes are not to be less than 50 mm bore.

**407** The arrangement of the overflow system is to be such that in the event of any one of the tanks being bilged, tanks situated in other watertight compartments of the ship cannot be flooded from the sea through the overflow main. In the case of trawlers and fishing vessels, the arrangement is to be such that in the event of any one of the tanks being bilged, the other tanks cannot be flooded from the sea through the overflow main.

Air and overflow pipes are to be arranged to be self-draining under normal conditions of trim.

**408** Overflow pipes are to be fitted to oil fuel storage, settling and daily service tanks when the pressure head corresponding to the height of the air pipe is greater than that for which the tanks are suitable or when the sectional area of the air pipe is less than required by 406.

The pipe is to be led to an overflow tank of adequate capacity or to a storage tank having a space reserved for overflow purposes.

A sight glass is to be provided in the overflow pipe to indicate when the tanks are overflowing or, alternatively, an alarm device is to be provided to give warning either when the tanks are overflowing or when the oil reaches a predetermined level in the tanks.

**409** Where overflows from tanks which are used for the alternative carriage of oil and water ballast are connected to an overflow system, arrangements are to be made to prevent water ballast overflowing into tanks containing oil. *See also E 324.*

**410** Air and overflow pipes are to be of steel having a minimum thickness of 5 mm or other approved material and thickness. Steel pipes slightly less in thickness may be accepted, provided they be suitably coated to prevent corrosion. Where not in contact with oil fuel or cargo oil, suitable protection may be provided by galvanizing the pipes on completion.

The portions of air and overflow pipes fitted above deck are to be of steel or other approved ductile material and of robust construction.

Where flanged connections are employed, heavy flanges with closely spaced bolts are to be fitted.

#### Sounding Pipes

**411** Provision is to be made for sounding all tanks, and the bilges of those compartments which are not at all times readily accessible.

The soundings are to be taken as near the suction pipes as practicable.

**412** Sounding pipes, including those for the double bottom tanks below the machinery spaces, are to be led to positions above the bulkhead deck which are at all times accessible and, in the case of oil fuel tanks and lubricating oil tanks, all sounding pipes are to be led to safe positions outside the machinery space. For short sounding pipes and alternative means of sounding, *see* 413, 414 and 415.

These pipes should be as straight as practicable, and if curved to suit the structure of the ship, the curvature must be sufficiently easy to permit the ready passage of the sounding rod or chain.

Nameplates are to be affixed to the upper ends of all sounding pipes. For closing requirements, *see also* D 2912, quoted at the end of this Section.

**413** In machinery spaces and tunnels where it is not always practicable to extend the sounding pipes as mentioned in 412, short sounding pipes extending to readily accessible positions above the platform may be fitted.

Short sounding pipes to oil fuel and lubricating oil tanks are to be fitted with cocks having parallel plugs with permanently attached handles so loaded that, on being released, they automatically close the cocks. As a further precaution against fire, such sounding pipes are to be located in positions as far removed as possible from any heated surface or electrical equipment and, where necessary, effective shielding is to be provided in way of such surfaces and/or equipment.

Short sounding pipes to tanks other than oil tanks are to be fitted with shut-off cocks or with screw caps attached to the pipes by chains.

In passenger ships, short sounding pipes are permissible only for sounding cofferdams and double bottom tanks situated in the machinery space and are in all cases to be fitted with self-closing cocks as described in the foregoing.

**414** Tank sounding devices of approved type may be used in lieu of sounding pipes. These devices are to be tested, after fitting on board, to the satisfaction of the Surveyors.

**415** If gauge glasses are used for indicating the level of liquid in tanks containing lubricating oil, oil fuel or other flammable liquid, the glasses are to be of heat-resisting quality adequately protected from mechanical damage and fitted with self-closing valves at the lower ends and at the top ends if these are connected to the tanks below the maximum liquid level.



**416** Sounding pipes to oil compartments are not to terminate within refrigerated cargo chambers or in the fan and battery rooms for these chambers, nor are these pipes to terminate in enclosed spaces from which access is provided to refrigerated cargo chambers or their fan and battery rooms, if it be practicable to avoid doing so.

Where these sounding pipes do terminate in such spaces they are to be fitted with self-closing cocks having parallel plugs.

**417** Sounding pipes are not to be less than 32 mm bore. All sounding pipes, whether the compartments or tanks, which pass through refrigerated spaces or the insulation thereof, in which the temperatures contemplated are 0°C or below, are not to be less than 65 mm bore.

**418** All pipes, including scupper pipes, air pipes and sounding pipes which pass through chambers intended for the carriage or storage of refrigerated produce are to be well insulated.

Where such pipes pass through chambers intended for a temperature of 0°C or below, they are also to be insulated from the steel structure except in positions where the temperature of the structure is mainly controlled by the external temperature and will normally be above freezing point. Pipes passing through a deck plate within the ship side insulation, where the deck is fully insulated below and has an insulation ribband on top, are to be attached to the deck plating.

In the case of pipes adjacent to the shell plating, metallic contact between the pipes and the shell plating or frames is to be arranged so far as practicable.

The air refreshing pipes to and from refrigerated compartments need not, however, be insulated from the steel work.

**419** Sounding pipes are to be of steel having a minimum thickness of 4,5 mm or other approved material and thickness. Steel pipes slightly less in thickness may be accepted, provided they be suitably coated to prevent corrosion. Where not in contact with oil fuel or cargo oil, suitable protection may be provided by galvanizing the pipes on completion.

Where flanged connections are employed, heavy flanges with closely spaced bolts are to be fitted.

**420** Striking plates of adequate thickness and size are to be fitted under open ended sounding pipes.

Where slotted sounding pipes having closed ends are employed, the closing plugs are to be of substantial construction.

**421** Elbow sounding pipes are not to be used for deep tanks unless the elbows and pipes are situated within closed cofferdams or within tanks containing similar liquids.

They may, however, be fitted to other tanks and may be used for sounding bilges, provided it is not practicable to lead them direct to the tanks or compartments.

The elbows are to be of heavy construction and adequately supported.

In passenger ships, elbow sounding pipes are not permissible.

#### Extract from Chapter D for reference

NOTE. For ships under 90 m in length, see SD 2911 to SD 2914 in the *Rules for Small Ships*.

#### **Air and Sounding Pipes**

**D 2911** The height of air pipes from the upper surface of decks exposed to the weather, to the point where water may have access below is not normally to be less than:—

On the freeboard deck ... 760 mm

On superstructure decks ... 450 mm

These heights are to be measured above sheathing, where fitted.

Lower heights may be approved in cases where these are essential for the working of the ship, provided the design and arrangements are otherwise satisfactory.

**D 2912** All openings of air and sounding pipes are to be provided with permanently attached satisfactory means of closing to prevent the free entry of water.

**D 2913** Striking plates of suitable thickness, or their equivalent, are to be fitted under all sounding pipes.

**D 2914** Air and sounding pipes are to be well protected in all spaces. This protection is to be of steel in bulk cargo spaces or their equivalent, and also in areas where contact with large containers, wheeled vehicles or similar items is a possibility.

#### Section 5

#### **PRESSURE PIPES**

##### **General**

**501** The requirements of this Section, unless otherwise specifically stated, are primarily intended for piping systems in which the design pressure is 0,69 N/mm<sup>2</sup> (7 kgf/cm<sup>2</sup>) and over.



**Copper and Copper Alloy Pipes**

502 Copper and copper alloy pipes are to be seamless or of approved welded type.

Branches are to be provided by cast or stamped fittings, by pipe pressings, or by other approved fabrications.

503 Brazing and welding materials are to be suitable for the operating temperature and for the medium being carried. All brazing and welding is to be carried out to the satisfaction of the Surveyors.

504 The maximum working temperatures permitted for pipe and branch materials are indicated in Table E 5.1. Where it is proposed to use other copper alloys, particulars of chemical composition and mechanical properties at the working temperature including, if applicable, creep and rupture data, are to be submitted for consideration.

505 The minimum thickness,  $T$ , of straight seamless copper and copper alloy pipes is to be determined by the following formula:—

$$T = \frac{PD}{2f + P} + c$$

where  $T$  = thickness, in mm,

$P$  = design pressure, in  $N/mm^2$  ( $kgf/cm^2$ ), which in the case of feed pipes is to be 1,25 times the boiler design pressure,

$D$  = outside diameter, in mm,

$f$  = allowable stress, in  $N/mm^2$  ( $kgf/cm^2$ ), from Table E 5.1. Intermediate values of stresses to be obtained by linear interpolation,

$c$  = corrosion allowance,

= 0,8 mm for copper, aluminium brass, and copper nickel alloys where the nickel content is less than 10 per cent,

= 0,5 mm for copper nickel alloys where the nickel content is 10 per cent or greater,

= 0, where the media is non-corrosive relative to the pipe material.

**NOTES.**

1. The value of  $T$  is the minimum thickness for straight pipes, and provision must be made for any minus tolerance to which the pipes may be manufactured.

2. Practical considerations such as manufacture, fabrication and robustness may make it necessary for pipes thicker than this minimum to be used. In such cases, the nominal pipe thickness should, in general, not be less than shown in Table E 5.1A for the appropriate standard pipe size.

506 The minimum thickness,  $T_b$ , of a straight seamless copper or copper alloy pipe to be used for a pipe bend is to be determined by the formula below, except where it can be demonstrated that the use of a thickness less than  $T_b$  would not reduce the thickness below  $T$  at any point after bending.

$$T_b = T + b$$

where  $b$  = bending allowance.

The radius of curvature at the centreline of the pipe is not to be less than twice the outside diameter of the pipe.

In general, the bending allowance is not to be less than:—

$$b = \frac{D}{2,5 R} T \text{ mm}$$

where  $R$  = bending radius to the centreline of the pipe, in mm.

**TABLE E 5.1**

PIPE MATERIAL	MATERIAL CONDITION	MINIMUM TENSILE STRENGTH $N/mm^2$ ( $kgf/mm^2$ )	ALLOWABLE STRESS, in $N/mm^2$ ( $kgf/cm^2$ )										
			50°C	75°C	100°C	125°C	150°C	175°C	200°C	225°C	250°C	275°C	300°C
Copper	annealed	220 (22)	41,2 (420)	41,2 (420)	40,2 (410)	40,2 (410)	34,3 (350)	27,5 (280)	18,6 (190)				
Aluminium Brass	annealed	320 (33)	78,5 (800)	78,5 (800)	78,5 (800)	78,5 (800)	78,5 (800)	51,0 (520)	24,5 (250)				
Copper Nickel 95/5 & 90/10	annealed	270 (28)	68,6 (700)	68,6 (700)	67,7 (690)	65,7 (670)	63,7 (650)	61,8 (630)	58,8 (600)	55,9 (570)	52,0 (530)	48,1 (490)	44,1 (450)
Copper Nickel 70/30	annealed	360 (37)	81,4 (830)	79,4 (810)	77,5 (790)	75,5 (770)	73,5 (750)	71,6 (730)	69,6 (710)	67,7 (690)	65,7 (670)	63,7 (650)	61,8 (630)



## NOTES.

1. The value of  $T_b$  is the minimum thickness, and provision must be made for any minus tolerance to which the pipes may be manufactured.

2. Practical considerations such as manufacture, fabrication and robustness may make it necessary for pipes thicker than this minimum to be used. In such cases, the nominal thickness of a straight copper or copper alloy pipe to be used for a pipe bend should, in general, not be less than shown in Table E 5.1A for the appropriate standard pipe size.

TABLE E 5.1A

STANDARD PIPE SIZES OUTSIDE DIAMETER		MINIMUM OVERRIDING NOMINAL THICKNESS	
		COPPER	COPPER ALLOY
mm	mm	mm	mm
8 to 10		1,0	0,8
12 to 20		1,2	1,0
25 to 44,5		1,5	1,2
50 to 76,1		2,0	1,5
88,9 to 108		2,5	2,0
133 to 159		3,0	2,5
193,7 to 267		3,5	3,0
273 to 457,2		4,0	3,5
508		4,5	4,0

507 Pipes which have been hardened by cold bending are to be suitably heat treated on completion of fabrication and prior to testing by hydraulic pressure. Copper pipes are to be annealed and copper alloy pipes are to be either annealed or stress relief heat treated.

## Steel Pipes

508 Steel pipes for a design pressure exceeding  $1,72 \text{ N/mm}^2$  ( $17,5 \text{ kgf/cm}^2$ ) or a temperature exceeding  $220^\circ\text{C}$ , and all feed pipes and pressure pipes conveying heated oil are to be manufactured and tested in accordance with the requirements of Q 7. Where it is proposed to use materials for pipes other than shown in Q 7, the information called for in 511 (a) is to be submitted for consideration.

509 Pipes other than those mentioned in 508 may be made and tested

- (a) to the requirements of Q 7, or,
- (b) in accordance with an approved National Specification, except that forge butt welded pipes are not acceptable.

510 Pipes having forge butt welded longitudinal seams are not to be used for oil fuel systems, for heating coils in oil tanks, or for pressures exceeding  $0,34 \text{ N/mm}^2$  ( $3,5 \text{ kgf/cm}^2$ ).

511 The thickness of steel pipes intended for steam, feed, air, oil fuel and other pressure services is to be determined by the formulae in 512 and 513 and the following definitions are given in respect of the symbols used in the formulae:—

(a) The allowable stress,  $f$ , is obtained from the material properties of the appropriate category, grade and tensile range of steel indicated in Q 7 and is to be taken as the lowest of the following values:—

$$f = \frac{E_t}{1,6} \quad f = \frac{R_{20}}{2,7} \quad f = \frac{S_R}{1,6}$$

where  $E_t$  = specified minimum lower yield stress or 0,2 per cent proof stress at the temperature under consideration,

$R_{20}$  = specified minimum tensile strength at room temperature,

$S_R$  = average stress to produce rupture in 100 000 hours at the temperature under consideration.

In general, when determining the value of the allowable stress,  $f$ , the temperature of the pipeline is to be taken as the maximum temperature of the internal fluid, but in no case is to be less than  $100^\circ\text{C}$ . In the case of pipes for superheated steam the temperature is to be taken as the designed operating steam temperature for the pipeline provided the temperature at the superheater outlet is closely controlled. Where temperature fluctuations exceeding  $14^\circ\text{C}$  above the designed temperature are to be expected in normal service the steam temperature to be used for determining the allowable stress is to be increased by the amount of this excess.

Values of the allowable stress,  $f$ , are shown in Tables E 5.2 and E 5.3. For intermediate temperatures, values of the allowable stress may be obtained by interpolation.

Where it is proposed to use, for high temperature service, alloy steels other than those stated in Q 7, particulars of the tube sizes, design conditions and appropriate national or proprietary material specifications are to be submitted for consideration.

Where the material does not conform to an established standard, particulars of the chemical composition, deoxidizing medium, heat treatment, mechanical properties, and measured or estimated long-term stress to rupture data at the proposed operating temperature, are to be submitted for the purpose of assessing a safe allowable stress.

TABLE E 5

GRADE OF STEEL	YIELD STRESS N/mm <sup>2</sup>	TENSILE STRENGTH N/mm <sup>2</sup>	ALLOWABLE STRESS in N/mm <sup>2</sup> (see E 511)													
			100°C	150°C	200°C	250°C	300°C	350°C	390°C	400°C	410°C	420°C	430°C	440°C	450°C	460°C
Carbon	210	340-460	114,2	112,8	110,3	103,9	91,2	80,9	75,0	73,5	65,7	57,9	51,0	44,6	39,7	34,3
Carbon	245	410-530	125,5	123,6	118,7	111,8	98,6	89,7	86,8	76,5	65,7	57,9	51,0	44,6	39,7	34,3
1 Cr— $\frac{1}{2}$ Mo	230	410-620	139,3	134,8	129,9	116,7	102,5	92,7	91,2	91,2	90,7	90,2	89,7	89,2	88,8	88,3
$2\frac{1}{4}$ Cr-1 Mo (NOTE 1)	230	410-560	122,1	111,3	95,6	92,7	89,7	85,8	83,4	82,9	82,4	81,9	81,4	80,9	80,9	80,9
$2\frac{1}{4}$ Cr-1 Mo (NOTE 2)	265	490-690	157,9	156,4	153,0	146,1	141,2	134,8	129,4	128,0	126,5	125,5	124,5	123,6	122,6	121,6
$\frac{1}{2}$ Cr— $\frac{1}{2}$ Mo— $\frac{1}{4}$ V	295	460-610	157,9	156,4	153,0	146,1	141,2	134,8	129,4	128,0	126,5	125,5	124,5	123,6	122,6	121,6

or in metric units:—

TABLE E 5

GRADE OF STEEL	YIELD STRESS kgf/mm <sup>2</sup>	TENSILE STRENGTH kgf/mm <sup>2</sup>	ALLOWABLE STRESS in kgf/cm <sup>2</sup> (see E 511)													
			100°C	150°C	200°C	250°C	300°C	350°C	390°C	400°C	410°C	420°C	430°C	440°C	450°C	460°C
Carbon	21,3	35-47	1165	1150	1125	1060	930	825	765	750	670	590	520	455	405	350
Carbon	25,2	42-54	1280	1260	1210	1140	1005	915	885	780	670	590	520	455	405	350
1 Cr— $\frac{1}{2}$ Mo	23,6	42-63	1420	1375	1325	1190	1045	945	930	930	925	920	915	910	905	900
$2\frac{1}{4}$ Cr-1 Mo (NOTE 1)	23,6	42-57	1245	1135	975	945	915	875	850	845	840	835	830	825	825	825
$2\frac{1}{4}$ Cr-1 Mo (NOTE 2)	26,8	50-70	1610	1595	1560	1490	1440	1375	1320	1305	1290	1280	1270	1260	1250	1240
$\frac{1}{2}$ Cr— $\frac{1}{2}$ Mo— $\frac{1}{4}$ V	30,0	47-62	1610	1595	1560	1490	1440	1375	1320	1305	1290	1280	1270	1260	1250	1240

NOTES. 1. Annealed condition.  
2. Normalized and tempered condition.



## CATEGORY I MATERIAL

ALLOWABLE STRESS in N/mm <sup>2</sup> (see E 511)														TENSILE STRENGTH N/mm <sup>2</sup>	YIELD STRESS N/mm <sup>2</sup>	GRADE OF STEEL
470°C	480°C	490°C	500°C	510°C	520°C	530°C	540°C	550°C	560°C	570°C	580°C	590°C	600°C			
30,4	27,0													340-460	210	Carbon
30,4	27,0													410-530	245	Carbon
87,8	87,8	87,3	86,8	76,0	62,3	49,0	38,7	30,4	25,0	20,1				410-620	230	1 Cr-½ Mo
80,4	79,9	79,4	78,5	78,0	77,0	70,6	60,8	52,0	44,6	37,8	31,9	27,0	23,5	410-560	230	2½ Cr-1 Mo (NOTE 1)
120,6	119,1	117,7	104,9	92,7	80,9	70,6	60,8	52,0	44,6	37,8	31,9	27,0	23,5	490-690	265	2½ Cr-1 Mo (NOTE 2)
120,6	119,1	117,7	115,7	101,5	86,8	74,0	62,3	53,9	45,1	39,7	33,8			460-610	295	½ Cr-½ Mo-¼ V

## CATEGORY I MATERIAL

ALLOWABLE STRESS in kgf/cm <sup>2</sup> (see E 511)														TENSILE STRENGTH kgf/mm <sup>2</sup>	YIELD STRESS kgf/mm <sup>2</sup>	GRADE OF STEEL
470°C	480°C	490°C	500°C	510°C	520°C	530°C	540°C	550°C	560°C	570°C	580°C	590°C	600°C			
310	275													35-47	21,3	Carbon
310	275													42-54	25,2	Carbon
895	895	890	885	775	635	500	395	310	255	205				42-63	23,6	1 Cr-½ Mo
820	815	810	800	795	785	720	620	530	455	385	325	275	240	42-57	23,6	2½ Cr-1 Mo (NOTE 1)
1230	1215	1200	1070	945	825	720	620	530	455	385	325	275	240	50-70	26,8	2½ Cr-1 Mo (NOTE 2)
1230	1215	1200	1180	1035	885	755	635	550	460	405	345			47-62	30,0	½ Cr-½ Mo-¼ V

- NOTES. 1. Annealed condition.  
2. Normalized and tempered condition.

GRADE OF STEEL	YIELD STRESS N/mm <sup>2</sup>	TENSILE STRENGTH N/mm <sup>2</sup>	ALLOWABLE STRESS in N/mm <sup>2</sup> (see E 511)												
			100°C	150°C	200°C	250°C	300°C	350°C	400°C	410°C	420°C	430°C	440°C	450°C	460°C
Carbon	160	320-440	77,0	74,0	71,6	65,2	56,4	44,6	44,1	43,6	43,6	43,6	43,6	39,7	34,3
Carbon	175	340-460	83,4	81,4	79,9	71,6	62,3	51,5	50,5	50,5	50,5	50,5	44,6	39,7	34,3
Carbon	210	410-530	110,3	107,9	105,9	97,1	86,8	77,0	75,5	65,7	57,9	51,0	44,6	39,7	34,3
1 Cr- $\frac{1}{2}$ Mo	220	410-620	119,1	114,7	110,8	99,0	86,8	78,5	77,0	77,0	76,5	76,0	76,0	75,5	75,5
2 $\frac{1}{4}$ Cr-1 Mo (NOTE 1)	210	410-560	103,9	94,1	81,4	78,5	76,0	72,6	70,6	70,1	70,1	69,6	69,1	68,6	68,6
2 $\frac{1}{4}$ Cr-1 Mo (NOTE 2)	245	490-690	133,9	132,9	130,4	124,5	119,1	114,7	108,4	107,9	106,9	105,9	104,9	103,9	103,9
$\frac{1}{2}$ Cr- $\frac{1}{2}$ Mo- $\frac{1}{4}$ V	275	460-610	133,9	132,9	130,4	124,5	119,1	114,7	108,4	107,9	106,9	105,9	104,9	103,9	103,9

or in metric units:—

GRADE OF STEEL	YIELD STRESS kgf/mm <sup>2</sup>	TENSILE STRENGTH kgf/mm <sup>2</sup>	ALLOWABLE STRESS in kgf/cm <sup>2</sup> (see E 511)												
			100°C	150°C	200°C	250°C	300°C	350°C	400°C	410°C	420°C	430°C	440°C	450°C	460°C
Carbon	16,5	33-45	785	755	730	665	575	455	450	445	445	445	445	405	350
Carbon	17,8	35-47	850	830	815	730	635	525	515	515	515	515	455	405	350
Carbon	21,5	42-54	1125	1100	1080	990	885	785	770	670	590	520	455	405	350
1 Cr- $\frac{1}{2}$ Mo	22,5	42-63	1215	1170	1130	1010	885	800	785	785	780	775	775	770	765
2 $\frac{1}{4}$ Cr-1 Mo (NOTE 1)	21,5	42-57	1060	960	830	800	775	740	720	715	715	710	705	700	695
2 $\frac{1}{4}$ Cr-1 Mo (NOTE 2)	25,0	50-70	1365	1355	1330	1270	1215	1170	1105	1100	1090	1080	1070	1060	1055
$\frac{1}{2}$ Cr- $\frac{1}{2}$ Mo- $\frac{1}{4}$ V	28,0	47-62	1365	1355	1330	1270	1215	1170	1105	1100	1090	1080	1070	1060	1055

NOTES. 1. Annealed condition. 2. Normalized and tempered condition.



## CATEGORY II MATERIAL

ALLOWABLE STRESS in N/mm <sup>2</sup> (see E 511)														TENSILE STRENGTH N/mm <sup>2</sup>	YIELD STRESS N/mm <sup>2</sup>	GRADE OF STEEL
470°C	480°C	490°C	500°C	510°C	520°C	530°C	540°C	550°C	560°C	570°C	580°C	590°C	600°C			
30,4	27,0													320-440	160	Carbon
30,4	27,0													340-460	175	Carbon
30,4	27,0	23,5	20,1											410-530	210	Carbon
74,5	74,5	74,0	74,0	73,5	62,3	49,0	38,7	30,4	25,0	20,1				410-620	220	1 Cr-½ Mo
67,7	67,7	67,2	66,7	66,7	66,2	65,2	60,8	52,0	44,6	37,8	31,9	27,0	23,5	410-560	210	2¼ Cr-1 Mo (NOTE 1)
102,5	101,5	100,0	98,6	92,7	80,9	70,6	60,8	52,0	44,6	37,8	31,9	27,0	23,5	490-690	245	2¼ Cr-1 Mo (NOTE 2)
102,5	101,5	100,0	98,6	97,1	86,8	74,0	62,3	53,9	45,1	39,7	33,8			460-610	275	½ Cr-½ Mo-¼ V

## CATEGORY II MATERIAL

ALLOWABLE STRESS in kgf/cm <sup>2</sup> (see E 511)														TENSILE STRENGTH kgf/cm <sup>2</sup>	YIELD STRESS kgf/cm <sup>2</sup>	GRADE OF STEEL
470°C	480°C	490°C	500°C	510°C	520°C	530°C	540°C	550°C	560°C	570°C	580°C	590°C	600°C			
310	275													33-45	16,5	Carbon
310	275													35-47	17,8	Carbon
310	275	240	205											42-54	21,5	Carbon
760	760	755	755	750	635	500	395	310	255	205				42-63	22,5	1 Cr-½ Mo
690	690	685	680	680	675	665	620	530	455	385	325	275	240	42-57	21,5	2¼ Cr-1 Mo (NOTE 1)
1045	1035	1020	1005	945	825	720	620	530	455	385	325	275	240	50-70	25,0	2¼ Cr-1 Mo (NOTE 2)
1045	1035	1020	1005	990	885	755	635	550	460	405	345			47-62	28,0	½ Cr-½ Mo-¼ V

NOTES. 1. Annealed condition. 2. Normalized and tempered condition.



(b) (i) The design pressure,  $P$ , for feed pipes is to be taken as 1,25 times the design pressure of the boiler, or the maximum pressure which can be developed in the feed line in normal service, whichever is the greater.

(ii) With water tube boiler installations the design pressure,  $P$ , is to be taken as the approved design pressure of the boiler for steam pipes between the boiler and integral superheater and as the pressure to which the superheater safety valves are set for the steam pipes leading from the superheater. Where the superheater safety valves are controlled by pilot valves operated from the saturated steam drum, then the design pressure for the steam pipes leading from the superheater is to be taken as the design pressure of the boiler.

NOTE. In installations where the boiler pressure, as controlled by the safety valve settings, is less than the design pressure of the boiler, it will be permissible for thicknesses of external steam and feed pipes to be based on the former.

- (c) The thickness,  $T$ , determined by the formula in 512 is the minimum thickness for straight pipes and the thickness,  $T_b$ , determined by the formulae in 513 is the minimum thickness of a straight pipe from which a pipe bend is to be made. In both cases provision must be made for any minus tolerance to which the pipes may be manufactured.
- (d) The outside diameter,  $D$ , of the pipe may be subject to manufacturing tolerances but these tolerances are not to be used in the evaluation of formulae.

**512** The minimum thickness of straight steel pipes intended for the services referred to in 511 is to be determined by the following formula:—

$$T = \frac{CPD}{2f + P}$$

where  $T$  = minimum thickness, in mm. (See Notes 1 and 2),  
 $P$  = design pressure, in  $N/mm^2$  ( $kgf/cm^2$ ),  
 $D$  = outside diameter of pipe, in mm,  
 $f$  = allowable stress, in  $N/mm^2$  ( $kgf/cm^2$ ), from Tables E 5.2 or E 5.3, the symbols being as defined in 511,  
 $C = 1,4$  for oil fuel pipes and steam heating pipes in contact with oil,  
 $= 1,0$  for all other pipes.

For pipes intended for the services permitted by 509 and made and tested in accordance with 509 (b) the allowable stress is to be taken as 80 per cent of the values given in Table E 5.3 for the appropriate specified minimum tensile strength.

The formula does not provide for adverse corrosion conditions. In the case of steam and feed pipes over 25 mm bore intended for low pressure boilers having design pressures up to  $1,72 N/mm^2$  ( $17,5 kgf/cm^2$ ), and for any boilers with open feed systems, these pipes are to be made 1,0 mm thicker than required by the formula.

#### NOTES.

1. The value of  $T$  is the minimum thickness for straight pipes and provision must be made for any minus tolerance to which the pipes may be manufactured. (See Q 707 (c) for tolerance on wall thickness.)

2. Practical considerations such as manufacture, fabrication and robustness may make it necessary for pipes thicker than this minimum to be used. In such cases, the nominal pipe thickness should in general, not be less than shown in Table E 5.4 for the appropriate standard pipe size.

**513** The minimum thickness,  $T_b$ , of a straight steel pipe to be used for a pipe bent to a radius in accordance with Table E 5.5 is to be determined by the formulae below, except where it can be demonstrated that the use of a thickness less than  $T_b$  would not reduce the thickness below  $T$  at any point after bending. See Notes 1 and 2.

- (a) For pipes bent to the radii specified in Table E 5.5 Columns 2 and 4:—

$$T_b = 1,125 T \quad (1)$$

- (b) For pipes exceeding 220 mm outside diameter, and where  $T$  is 32 mm or more, bent to the radii specified in Table E 5.5. Column 5:—

$$T_b = 1,1 T \quad (2)$$

#### NOTES.

1. The value of  $T_b$  is the minimum thickness and provision must be made for any minus tolerance to which the pipes may be manufactured. See Q 707 (c) for tolerance on wall thickness.

2. Practical considerations such as manufacture, fabrication and robustness may make it necessary for pipes thicker than this minimum to be used. In such cases, the nominal thickness of a straight steel pipe to be used for a pipe bend should in general, not be less than shown in Table E 5.4.

**514** Any proposal to bend pipes to smaller radii than shown in Table E 5.5 will be the subject of special consideration and further allowance is to be made for thinning at the outside of the bend, except where it can be demonstrated that the use of a thickness  $T_b$  would not reduce the thickness below  $T$  at any point after bending.



TABLE E 5.4

STANDARD PIPE SIZES—OUTSIDE DIAMETER		MINIMUM OVERRIDING NOMINAL THICKNESS
EXCEEDING	NOT EXCEEDING	
mm	mm	mm
—	10,2	1,6
10,2	17,2	1,8
17,2	26,9	2,0
26,9	33,7	2,3
33,7	54,0	2,6
54,0	76,1	2,9
76,1	88,9	3,2
88,9	114,3	3,6
114,3	139,7	4,0
139,7	168,3	4,5
168,3	193,7	5,4
193,7	219,1	5,9
219,1	273,0	6,3
273,0	323,9	7,1
323,9	368,0	8,0
368,0	419,0	8,8

TABLE E 5.5

Minimum bending radii for steel pipes of thickness determined by the formulæ in E 513.

1	2	3	4	5
OUTSIDE DIAMETER	RADIUS MEASURED TO CENTRELINE OF PIPE	OUTSIDE DIAMETER	RADI MEASURED TO CENTRELINE OF PIPE	
	$T_b = 1,125T$ ALL THICKNESSES		$T_b = 1,125T$ ALL THICKNESSES	$T_b = 1,1T$ $T_b = 35$ mm OR ABOVE
mm	mm	mm	mm	mm
26,9	63	244,5	810	1140
33,7	76	273,0	1020	1270
42,4	101	298,5	1120	1400
48,3	114	323,9	1220	1520
60,3	152	355,6	1500	1780
76,1	190	381,0	1600	1900
88,9	228	406,4	1730	2030
101,6	267	457,2	2030	2280
114,3	305			
127,0	355			
139,7	380			
152,4	430			
165,1	460			
168,3	460			
177,8	580			
193,7	630			
219,1	710			

There is a minimum thickness for each size of pipe dependent on bending procedure below which the allowance for thinning will be exceeded, and in such cases the radius given in Table E 5.5 is to be increased where necessary to ensure that the thickness is not below  $T$  at any point after bending.

### Pipe Joints

515 Joints in pressure pipe lines may be made by bolted flanges or by butt welds between pipes or between pipes and valve chests, or other fittings, but with the latter system it is desirable that a few flanged joints be provided at suitable positions to facilitate installation, cold "pull up" and inspection at periodical surveys.

Where pressure pipe lines are assembled and butt welded in place the piping is to be arranged well clear of adjacent structures, to permit sufficient access for pre-heating, welding, heat treatment and examination of the joints.

When hydraulic testing the pipe lines, the test pressure  $P_T$  is to be in accordance with 523 or twice the design pressure, whichever is the lesser; terminal valves should be capable of withstanding the same test pressure when closed. In the supporting and securing arrangements for the pipe lines, provision is to be made for these hydraulic test conditions.

### Steel Pipe Flanges

516 Flanges are to be weldless and of material suitable for the design temperature. They may be attached to pipes by screwing and expanding or by welding depending upon the pressures and temperatures for which the various types are acceptable as indicated in Table E 5.6. Acceptable methods of attachment are illustrated in Fig. E 5.1.

If backing rings are used with flange type (a) they are to fit closely to the bore of the pipe and should be removed after welding. The rings are to be made of the same material as the pipes or of good quality mild steel having a sulphur content not greater than 0,06 per cent. The use of flange types (b) and (c) with alloy steel pipes is limited to pipes up to and including 150 mm outside diameter. Flange types (c) and (e) are unsuitable for pipes under 75 mm bore.

Alternative methods of flange attachment and other types of pipe joints may be accepted provided details are submitted for special consideration.

For flange types (b) and (c), dimension  $X$  is to be taken as  $T$  for carbon steel and  $2T$  for alloy steel pipes but is not to be less than shown in the Table associated with Fig. E 5.1.

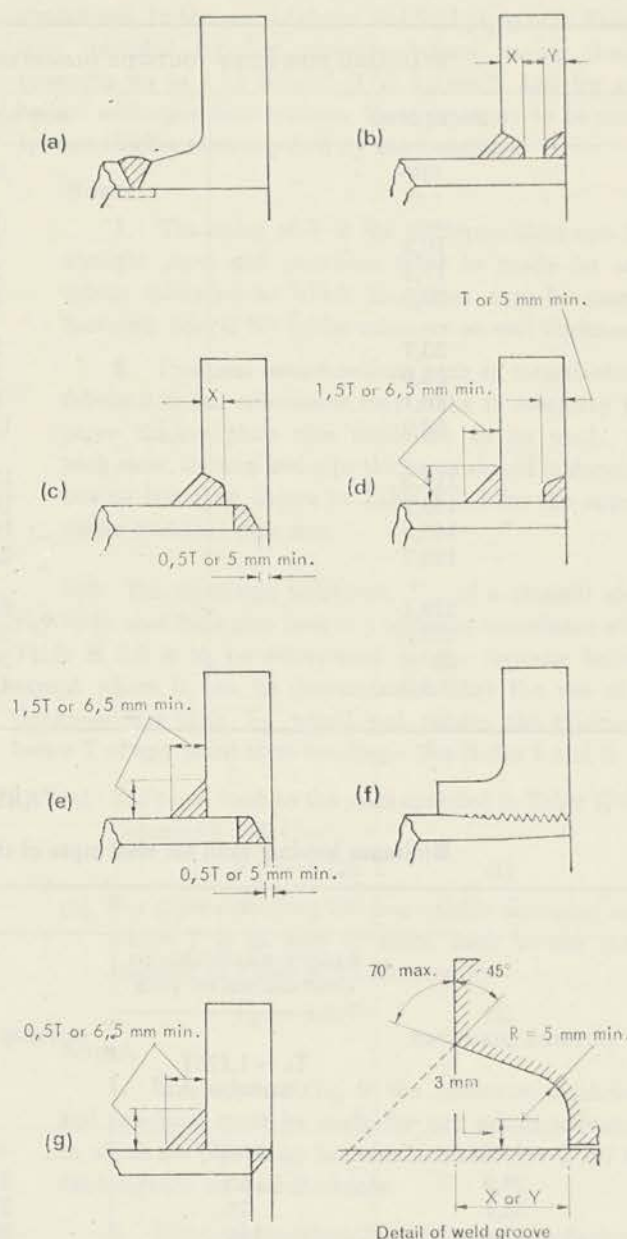


FIG. E 5.1 ACCEPTABLE METHODS OF ATTACHING FLANGES TO STEEL PIPES

PIPE BORE	DIMENSION $\times$ MINIMUM
13 mm and 19 mm	6,5 mm
25 mm to 38 mm	8,0 mm
50 mm and over	9,5 mm



For flange type (b), dimension Y is to be taken as T for carbon steel and 2T for alloy steel pipes but is not to be less than 5 mm.

T is to be taken as the Rule thickness of the pipe.

517 Where flanges are secured by screwing, the pipe and flange are to be screwed with a vanishing thread and the diameter of the screwed portion of the pipe over the thread is not to be appreciably less than the outside diameter of the unscrewed pipe. After the flange has been screwed hard home the pipe is to be expanded into the flange.

TABLE E 5.6

TYPE OF FLANGE ATTACHMENT	SERVICE AND RATING			
	FEED, AIR, OIL FUEL AND OTHER FLUIDS		STEAM	
	Pressure N/mm <sup>2</sup> (kgf/cm <sup>2</sup> )	Temperature °C	Pressure N/mm <sup>2</sup> (kgf/cm <sup>2</sup> )	Temperature °C
(a), (b) & (c)	All Conditions		All Conditions	
(d) & (e)	5,15 (52,5)	260	3,78 (38,5)	400
(f)	4,12 (42,0)		3,09 (31,5)	
(g)	1,72 (17,5)		1,72 (17,5)	260

The vanishing thread on a pipe is not to be less than three pitches in length, and the diameter at the root of the thread is to increase uniformly from the standard root diameter to the diameter at the top of the thread. This may be produced by suitably grinding the dies, and the flange should be tapered out to the same formation.

#### Welded Flanges, Pipe Joints and Branch Pieces

518 Welding may be carried out by means of the shielded metal arc, inert gas metal arc, oxy-acetylene or other approved process, but in general, oxy-acetylene welding is suitable only for flange type (a) and is not to be applied to pipes exceeding 100 mm diameter or 9,5 mm thick.

When flanges are attached by welding or pipe-to-pipe joints are butt welded using the oxy-acetylene or metal arc process the filler rods, electrodes and fusible root inserts used are to be suitable for the materials of the parts to be joined.

All welding work is to be carried out in shop or ship in positions free from draughts or rapid changes of temperature.

Preheating under temperature control is to be employed when necessitated by the dimensions and composition of the materials to be welded and is to be effected by a method which ensures uniformity of temperature at the joint. The method of heating and the means adopted for temperature control are to be to the satisfaction of the Surveyors.

Where butt welds are employed in the attachment of flange type (a), in pipe-to-pipe joints or in the construction of branch pieces, the adjacent pieces are to be matched at the bores. This may be effected by drifting, roller expanding or machining provided the pipe wall is not reduced below the designed thickness. If the parts to be joined differ in wall thickness, the thicker wall is to be gradually tapered to that of the thinner at the butt joint. The welding necks of valve chests are to be sufficiently long to ensure that the valves are not distorted as the result of welding and subsequent heat treatment of the joints.

Butt welds may be reinforced externally by additional runs of weld metal. All welds in high pressure and high temperature pipe lines are to have a smooth surface finish and even contour; if necessary they are to be made smooth by grinding. No undercutting of the pipe at the edges of the weld is acceptable.

519 Branches may be attached to pressure pipes by means of welding provided the pipe is reinforced at the branch by a compensating plate or collar or other approved means, or alternatively the thicknesses of pipe and branch are to be increased to maintain the strength of the pipe.

These requirements also apply to fabricated branch pieces.

520 The welding procedure proposed for the attachment of flanges, valve chests and other fittings to pipes, pipes-to-pipes and the fabrication of branch pieces, whether in carbon or alloy steel, is to be approved by the Surveyors in the first instance before work is commenced. For this purpose representative specimens of such parts will be required for examination and test.

TABLE E 5.7

PIPE STEEL	TEMPERATURE LIMITS FOR STRESS RELIEVING
Carbon	580-620°C
1 Cr-½ Mo	620-670°C
2½ Cr-1 Mo	650-690°C
½ Cr-½ Mo-¼ V	650-710°C

TABLE E 5.8

## Category I Material

GRADE OF STEEL	YIELD STRESS		TENSILE STRENGTH		CONSTANT K	
	N/mm <sup>2</sup>	(kgf/mm <sup>2</sup> )	N/mm <sup>2</sup>	(kgf/mm <sup>2</sup> )	SI	(metric)
Carbon	210	(21,3)	340-460	(35-47)	310	(3160)
Carbon	245	(25,2)	410-530	(42-54)	370	(3790)
1 Cr- $\frac{1}{2}$ Mo	230	(23,6)	410-620	(42-63)	345	(3510)
$2\frac{1}{4}$ Cr-1 Mo (NOTE 1)	230	(23,6)	410-560	(42-57)	345	(3510)
$2\frac{1}{4}$ Cr-1 Mo (NOTE 2)	265	(26,8)	490-690	(50-70)	392	(4000)
$\frac{1}{2}$ Cr- $\frac{1}{2}$ Mo- $\frac{1}{4}$ V	295	(30,0)	460-610	(47-62)	440	(4490)

- NOTES. 1. Annealed condition.  
2. Normalized and tempered condition.

TABLE E 5.9

## Category II Material

GRADE OF STEEL	YIELD STRESS		TENSILE STRENGTH		CONSTANT K	
	N/mm <sup>2</sup>	(kgf/mm <sup>2</sup> )	N/mm <sup>2</sup>	(kgf/mm <sup>2</sup> )	SI	(metric)
Carbon	160	(16,5)	320-440	(33-45)	242	(2470)
Carbon	175	(17,8)	340-460	(35-47)	262	(2670)
Carbon	210	(21,5)	410-530	(42-54)	316	(3230)
1 Cr- $\frac{1}{2}$ Mo	220	(22,5)	410-620	(42-63)	330	(3370)
$2\frac{1}{4}$ Cr-1 Mo (NOTE 1)	210	(21,5)	410-560	(42-57)	316	(3230)
$2\frac{1}{4}$ Cr-1 Mo (NOTE 2)	245	(25,0)	490-690	(50-70)	365	(3720)
$\frac{1}{2}$ Cr- $\frac{1}{2}$ Mo- $\frac{1}{4}$ V	275	(28,0)	460-610	(47-62)	412	(4210)

- NOTES. 1. Annealed condition.  
2. Normalized and tempered condition.



The assembly for the weld procedure test and the welding technique should simulate the conditions under which the work is to be done on the installation. Test welds are to be examined for defects by the appropriate method specified in 521. The test welds are then to be sectioned at positions selected by the Surveyor, one surface of each section being prepared, etched and examined for defects in the weld and heat affected zones. In the case of pipes or branch pieces of alloy steel, mechanical tests and tests to destruction may also be required to demonstrate that the joints are of adequate strength. Check tests of the quality of the work of the welders are to be carried out periodically at the Surveyor's discretion.

**521** All welds attaching flanges and branches to alloy steel pipes of 76 mm bore and over are to be examined to ensure as far as possible that the welds are satisfactory. These examinations are to be carried out by radiography where practicable or by other approved methods.

All butt welded joints in steam pipe lines, where the outside diameter exceeds 76,1 mm, when made of carbon steel for the design conditions referred to in 508, or of low alloy steel, are to be examined by radiographic or other approved methods. The techniques are to be applied to the satisfaction of the Surveyor and are to be of a sensitivity which is suitable to disclose detrimental defects. For radiographic examinations and required standards of sensitivity, see J 420 to J 423.

Fillet welds in fabricated branch pieces are to be examined by magnetic crack detection methods.

Small detrimental defects, if found, are to be cut out and the seam re-welded and re-examined. In the case of major defects the joint is to be re-machined and completely re-welded.

#### Heat Treatment of Steel Pipes and Branch Pieces

**522** Carbon steel pipes and fabricated branch pieces having a thickness of 19 mm and over are to be stress relieved on completion of welding. Where oxyacetylene welding has been employed, however, all the pipes and branch pieces are to be normalized on completion of welding in accordance with the requirements of Table Q 7.2.

All alloy steel pipes and fabricated branch pieces are to be carefully and suitably heat treated in accordance with the requirements of Table Q 7.2 after:—

- (a) oxy-acetylene welding, or
- (b) being heated for forming or bending operations, or
- (c) being cold bent to a radius measured at the centre-line of the pipe of less than 3,5 D.

After electric arc welding all alloy steel pipes and branch pieces are to be given a stress relieving heat treatment.

Suitable temperatures for stress relieving carbon and alloy steel pipes and branch pieces are given in Table E 5.7 and should be maintained for one hour per 25 mm of wall thickness.

#### Hydraulic Test Pressures

**523** (a) All copper and copper alloy main steam and feed pipes are, on completion, to be tested by hydraulic pressure to not less than twice the design pressure as defined in 505. Other copper and copper alloy pipes are to be similarly tested when intended for design pressures above 1,03 N/mm<sup>2</sup> (10,5 kgf/cm<sup>2</sup>).

(b) All steel pressure pipes, with the exception of those stated in (c) below, are on completion to be tested by hydraulic pressure to a pressure  $P_T$  determined by the following formula:—

$$P_T = \frac{K P}{2f}$$

where  $P_T$  = test pressure, in N/mm<sup>2</sup> (kgf/cm<sup>2</sup>),

$P$  = design pressure, in N/mm<sup>2</sup> (kgf/cm<sup>2</sup>),

$f$  = allowable stress, in N/mm<sup>2</sup> (kgf/cm<sup>2</sup>), at the design temperature, determined by 511 (a) and shown in Tables E 5.2 and E 5.3,

$K$  = a constant, depending on the pipe material, as indicated in Tables E 5.8 and E 5.9.

If the individual pipes are assembled and the joints butt welded in place, an additional hydraulic test to a pressure  $P_T$ , as indicated above, or to twice the design pressure, whichever is the lesser, is to be applied to the erected pipe line.

(c) Completed oil fuel pipes and heating coil systems, after fitting on board, are to be tested to twice the design pressure. See E 310, E 312 and E 335.

#### Cast Iron Heating Pipes

**524** Where it is desired to use pressure pipes of cast iron, details are to be submitted.

### Section 6

#### STEAM PIPE RANGES

##### Provision for Expansion

**601** In all steam pipe ranges provision is to be made for expansion and contraction to take place without unduly straining the pipes.

Where corrugated pipes are used, particulars are to be submitted.



**Drainage**

602 The slope of the pipes and the number and position of the drain valves or cocks are to be such that water can be efficiently drained from any portion of the steam pipe range when the ship is in normal trim and is either upright or has a list up to 5 degrees.

Arrangements are to be made for ready access to the drain valves or cocks.

**Pipes in way of Holds**

603 In general, steam pipes are not to be led through spaces which may be used for cargo, but where it is impracticable to avoid this arrangement, plans are to be submitted for consideration. The pipes are to be efficiently secured and insulated and well protected from mechanical damage. Pipe joints are to be as few as practicable and preferably butt welded. After fitting in place, the pipes are to be tested by hydraulic pressure to a pressure  $P_T$ , determined in accordance with E 523.

If these pipes are led through shaft tunnels, pipe tunnels in way of cargo holds or through duct keels, they are to be efficiently secured and insulated.

**Reduced Pressure Lines**

604 Pipe lines which are situated on the low pressure side of reducing valves and which are not designed to withstand the full pressure at the source of supply are to be fitted with pressure gauges and with relief valves having sufficient discharge capacity to protect the piping against excessive pressure.

**Valves and Fittings**

605 Valves and fittings intended either for steam pressures above 1,03 N/mm<sup>2</sup> (10,5 kgf/cm<sup>2</sup>) or temperatures above 218°C are to be of steel, carbon or low alloy, or other approved material suitable for the working temperature.

Castings of bronze, iron and carbon steel may be used within the following limits of temperature and pressure:—

Bronze	218°C	1,03 N/mm <sup>2</sup> (10,5 kgf/cm <sup>2</sup> )
Iron	232°C	1,03 N/mm <sup>2</sup> (10,5 kgf/cm <sup>2</sup> )
Carbon Steel	454°C	all pressures.

**Hydraulic Test Pressure**

606 All main steam and feed valves and fittings are to be tested by hydraulic pressure to not less than twice the working pressure as defined in E 506 and E 512. Other valves and fittings are to be similarly tested when intended for working pressures above 1,03 N/mm<sup>2</sup> (10,5 kgf/cm<sup>2</sup>).

For the testing of boiler mountings, see J 626 and J 639.

**Steam for Fire Extinguishing in Cargo Holds**

607 Where steam is used for fire extinguishing in cargo holds, provision is to be made to prevent damage to cargo by leakage of steam or by drip.

Details of the proposed precautionary measures are to be submitted.

**Section 7****BOILER FEED WATER SYSTEMS****Feed Pumps**

701 Two separate means of feed are to be provided for all main and auxiliary boilers which are required for essential services, with the exception of boilers in which steam is generated exclusively by exhaust gases or steam, where one means of feed will be accepted provided an alternative steam supply is available.

702 Two or more feed pumps are to be provided of sufficient capacity to supply the boilers under full load conditions with any one pump out of action.

703 Feed pumps may be worked from the main engines or may be independently driven but at least one of the pumps required in 702 is to be independently driven.

704 In twin screw ships in which there is only one independent feed pump each main engine is to be fitted with a feed pump. Where all the feed pumps are independently driven, the pumps are to be connected to deal with the condensate from both engines or from either engine.

705 Independent feed pumps required for feeding the main boilers are to be fitted with automatic regulators for controlling their output.

706 Where main-engine driven feed pumps are fitted and there is only one independent feed pump, a harbour feed pump or an injector is to be fitted to provide the second means of feed to the boilers which are in use when the main engines are not working. This requirement need not be complied with in the cases of trawlers and fishing vessels.

707 Feed pumps are to be provided with valves or cocks interposed between the pumps and the suction and the discharge pipes so that any pump may be opened up for overhaul while the others continue in operation.

**Sea Suctions**

708 One of the independent feed pumps is to be provided with an emergency suction to the sea, except in the cases mentioned in 709.



Suctions are also to be provided from this pump to the hotwell or condenser, unless suitable standby connections have already been provided for this purpose.

**709** The sea suction to a feed pump may be omitted if large reserve feed tanks are provided and an evaporator of adequate capacity is fitted.

#### Reserve Feed Water

**710** All ships fitted with boilers are to be provided with storage space for reserve feed water, the structural and piping arrangements being such that this water cannot be contaminated by oil or oily water. *See* D 940, D 1924 and D 1929 for structural arrangements.

#### General Service Pump

**711** An auxiliary independent feed pump may be used for general service, provided it is not connected to tanks containing oil fuel or cargo oil or to tanks, cofferdams and bilges containing oily water.

The valves on the suction pipes from the hotwell or condenser and the feed drain tank or filter are to be of non-return type.

#### Filters

**712** Where superheated steam is used in main or auxiliary engines of reciprocating type, filters are to be fitted to provide for the continuous filtration of the boiler feed water.

**713** Where a direct contact heater is supplied with exhaust steam from engines of reciprocating type, the feed water from the heater is to be led through the filters required by 712 or through additional filters arranged to provide for continuous filtration.

#### Cross-references

**714** For materials, working pressure and test pressure of feed pipes, *see* E 501 to E 523.

For feed water level regulators for water tube boilers, *see* J 636.

### Section 8

#### ENGINE COOLING WATER SYSTEMS

##### Main Supply

**801** Provision is to be made for an adequate supply of cooling water to the main propelling machinery and essential auxiliary engines, also to the lubricating oil and fresh water coolers and air coolers for electric propelling

machinery where these coolers are fitted. The cooling water pump(s) may be worked from the engines or be driven independently.

##### Alternative Supply

**802** Provision is also to be made for a separate emergency supply of cooling water from a suitable pump.

When selecting a pump for this purpose, consideration is to be given to the maximum pressure which it can develop if the overboard discharge valve is partly or fully closed and, when necessary, condenser doors, water boxes, etc., are to be protected by an approved device against inadvertent over-pressure. *See* H 838 for the hydraulic test pressure which condensers are required to withstand.

##### Sea Inlets

**803** Not less than two sea inlets are to be provided for the pumps supplying the salt water cooling system, one for the main pump and one for the standby pump. Alternatively, the sea inlets may be connected to a suction line available to main and standby pumps.

These inlets are to be low inlets and one of them may be the ballast pump or general service pump sea inlet.

##### Standby Fresh Water Pump

**804** Where fresh water cooling is employed, a standby fresh water pump need not be fitted if there be suitable emergency connections from a salt water system.

##### Cooling Water Supply to Auxiliaries

**805** Where each auxiliary is fitted with a cooling water pump, standby means of cooling need not be provided. Where, however, a group of auxiliaries is supplied with cooling water from a common system, a standby cooling water pump is to be provided for this system. This pump may be a suitable general service pump.

The auxiliary cooling water pumps are to be connected to not less than two sea inlets, preferably one on each side of the ship.

##### Strainers

**806** Where sea water is used for the direct cooling of the main engines and essential auxiliary engines, the cooling water suction pipes are to be provided with strainers which can be cleaned without interruption to the cooling water supply.

##### Relief Valves

**807** Cooling water pumps worked from the main engines are to be provided with relief valves on the pump discharge.



**Copper and Copper Alloy Piping Systems**

808 When non-ferrous pipes are proposed for fresh and sea water piping systems, details of the materials and the duty for which they are intended may be submitted to the Society for approval.

In the selection of components for sea water piping systems, care should be taken to avoid metal combinations which may lead to galvanic corrosion in service.

See Chapter R(D), *Guidance Notes on Metal Pipes for Water Services*.

**Section 9****LUBRICATING OIL SYSTEMS****Pumps**

901 In ships of unrestricted class in which the lubricating oil for the main engines (steam engines, oil engines, turbines or electric propelling motors), is circulated under pressure, a standby lubricating oil pump is to be provided where the following conditions apply:—

- (a) The lubricating oil pump is independently driven and the total output of the main engines exceeds 370 kW (500 shp).
- (b) One main engine with a built-in lubricating oil pump is fitted and the output of the engine exceeds 370 kW (500 shp).
- (c) Two or more main engines each with a built-in lubricating oil pump are fitted and the output of each engine exceeds 370kW (500 shp).

The standby pump is to be of sufficient capacity to maintain the supply of oil for normal conditions with any one pump out of action. The pump is to be fitted and connected ready for immediate use but where this is not convenient in the case of high speed oil engines with built-in pumps, a complete spare pump may be accepted for installation of type (c).

Similar provision is to be made where separate lubricating oil systems are employed for piston cooling, the operation of reverse reduction gears, oil operated couplings and controllable pitch propellers, unless approved alternative arrangements are provided.

902 Independently driven pumps of rotary type are to be fitted with a non-return valve on the discharge side of the pump.

**Control of Pumps**

903 The power supply to all independently driven pumps, delivering oil to main propulsion machinery for bearing lubrication and piston cooling is to be capable of

being stopped from a position which will always be accessible in the case of a fire taking place in the compartment in which they are situated, as well as from the compartment itself.

**Alarms**

904 All main and auxiliary engines and turbines intended for essential services are to be provided with means of indicating the lubricating oil pressure supply to them. Where such engines and turbines are of more than 37kW (50 horse power), audible and visible alarms are to be fitted to give warning of an appreciable reduction in pressure of the lubricating oil supply. Further, these alarms are to be actuated from the outlet side of any restrictions, such as filters, coolers, etc.

**Emergency Supply for Propulsion Turbines and Propulsion Turbo-Generators**

905 A suitable emergency supply of lubricating oil is to be arranged to come automatically into use in the event of a failure of the supply from the pump.

The emergency supply may be obtained from a gravity tank containing sufficient oil to maintain adequate lubrication for not less than 6 minutes, and in the case of propulsion turbo-generators until the unloaded turbine comes to rest from its maximum rated running speed.

Alternatively, the supply may be provided by the standby pump or by an emergency pump. These pumps are to be so arranged that their availability is not affected by a failure in the power supply.

**Filters**

906 Where the lubricating oil for main propelling engines is circulated under pressure, provision is to be made for the efficient filtration of the oil. The filters are to be capable of being cleaned without stopping the engine or reducing the supply of filtered oil to the engine.

907 Where filters are fitted on the discharge side of the lubricating oil pump, a relief valve in close circuit is to be fitted between the pump and the filter if the pump is capable of developing a pressure exceeding the design pressure of the system.

908 In the case of propulsion turbines and their gears, arrangements are to be made for the lubricating oil to pass through magnetic strainers and fine filters.

NOTE. It is recommended that the openings in the filter elements be not coarser than 50 micrometres, especially for the supply to turbine thrust bearings.

**Pipes and Fittings**

909 Extreme care is to be taken to ensure that lubricating oil pipes and fittings, before installation, are



free from scale, sand, metal particles and other foreign matter.

#### Lubrication of Bearings

**910** The arrangements for lubricating bearings and for draining crankcase and other oil sumps of main and auxiliary engines, gear cases, electric generators, motors and other running machinery are to be so designed that lubrication will remain efficient with the ship inclined from the normal at any angle up to 15 degrees transversely and when pitching 10 degrees longitudinally and when rolling up to 22,5 degrees from the vertical.

**911** For details of the requirements relating to the lubrication of bearings of electric generators and motors, see M 107.

#### Valves and Cocks

**912** Outlet valves and cocks on lubricating oil service tanks, other than double bottom tanks, situated in machinery spaces are to be capable of being closed locally and from positions outside the compartment which will always be accessible in the event of fire occurring in these spaces. Remote controls need only be fitted to outlet valves and cocks which are open in normal service and are not required for other outlets such as those on storage tanks. Instructions for closing the valves or cocks are to be indicated at the valves and cocks and at the remote control positions.

In the case of very small tanks consideration will be given to the omission of remote controls.

#### Cross-references

**913** For air and sounding pipes and gauge glasses, see E 404, E 413 and E 415.

### Section 10

#### PUMPING ARRANGEMENTS FOR SHIPS NOT FITTED WITH PROPELLING MACHINERY

##### Hand Pumps

**1001** Where auxiliary power is not provided, hand pumps are to be fitted in number and position as may be required for the efficient drainage of the ship.

The pumps are to be capable of being worked from the upper deck or from positions above the load waterline which are at all times readily accessible.

The suction lift is not to exceed 7,3 m, and is to be well within the capacity of the pump.

**1002** The sizes of the hand pumps are not to be less than given in Table E 10.1.

Where the ship is closely subdivided into small watertight compartments, 50 mm bore suctions will be accepted.

TABLE E 10.1

TONNAGE UNDER UPPER DECK	HAND PUMPS	
	Diameter of barrel of bucket pump	Bore of suction pipe of bucket pumps and semi-rotary pumps
Not exceeding 500 tons ...	mm 100	mm 50
Above 500 tons but not exceeding 1000 tons ...	115	57
Above 1000 tons but not exceeding 2000 tons ...	125	65
Above 2000 tons ...	140	70

##### Power Pumps

**1003** In ships in which auxiliary power is available on board, power pump suctions are to be provided for dealing with the drainage of tanks and of the bilges of the principal compartments.

The pumping arrangements are to be as required for self-propelled ships in so far as these requirements are applicable, duly modified to suit the size and service of the ship.

Details of the pumping arrangements are to be submitted for special consideration.

### Section 11

#### PETROLEUM AND OTHER LIQUID CARGOES HAVING A FLASH POINT BELOW 60°C (CLOSED CUP TEST)

##### General

**1101** The following requirements are based on the assumption that the ships are of normal tanker type having the main propelling machinery aft.

Departures from normal type will require special consideration.

See also Chapter R(J), *Provisional Rules for the Classification of Tankers Intended for the Carriage of Liquid Chemicals in Bulk*.



**1102** A complete system of piping and pumps is to be fitted for dealing with the cargo oil.

**1103** Oil engines are not to be situated within pump rooms, cofferdams or other spaces liable to contain petroleum or other explosive vapours, or in spaces or zones immediately adjacent to cargo oil or slop tanks.

For requirements for electrical equipment within such spaces, *see* M 16.

#### Cargo Pump Rooms

**1104** Cargo pump rooms are to be enclosed by oiltight bulkheads and are to have no direct communication with machinery spaces.

**1105** Provision is to be made for the bilge drainage of the cargo pump rooms by pump or bilge ejector suction. The cargo pumps or cargo stripping pumps may be used for this purpose, provided that the bilge suction is fitted with screw-down non-return valves and, in addition, an isolating valve or cock be fitted on the pump connection to the bilge chest. The pump room bilges of small tankers may be drained by means of a hand pump having a 50 mm bore suction.

Pump room suction is not to enter machinery spaces.

**1106** Pump rooms are to be provided with ready means of access.

#### Pump Room Ventilation

**1107** The pump room ventilation system is to be of the mechanical extraction type capable of 20 air changes per hour based on the gross volume of the pump room.

The ducting is to be arranged to permit extraction from the vicinity of the pump room bilges, immediately above the transverse floor plates or bottom longitudinals. An emergency intake is also to be arranged in the ducting at a height of 2.15 m above the pump room lower platform and is to be provided with a damper capable of being opened or closed from the weather deck and lower platform level. Means are to be provided to ensure the free flow of gases through the lower platform to the duct intakes.

The arrangement and materials of mechanical ventilator components are to be designed to prevent the risk of incendive sparking.

**1108** The vent exits from pump rooms are to discharge at least 3 m from the nearest air intakes or openings to accommodation and enclosed working spaces and from possible sources of ignition.

#### Cargo Pumps

**1109** Pumps for the purpose of filling or emptying the cargo oil tanks are to be used exclusively for this purpose,

except as provided in 1105. They are not to have any connections to compartments outside the range of cargo oil tanks.

Means are to be provided for stopping the cargo oil pumps from a position outside the pump rooms, as well as at the pumps.

**1110** The pumps are to be provided with effective escape valves which are to be in close-circuit, i.e. discharging to the suction side of the pumps.

Alternative proposals to safeguard against over pressure on the discharge side of the pump will be specially considered.

**1111** Where the cargo oil pumps are not driven by steam, plans of the arrangements for driving the pumps are to be submitted.

**1112** Where cargo pumps are driven by shafting which passes through a pump room bulkhead or deck, gastight glands with efficient means of lubrication are to be fitted to the shaft at the pump room plating.

#### Cargo Handling System

**1113** Expansion joints or bends are to be provided where necessary in the cargo pipe lines.

Terminal pipes, valves and other fittings in the cargo loading and discharging lines to which shore installation hoses are directly connected are to be of steel or other approved ductile material. They are to be of robust construction and strongly supported.

**1114** Where a ship is arranged for stern discharge, the discharge line is to be provided with a spectacle flange or removable spool piece at the poop or after deckhouse front and a blank flange at the stern end, irrespective of the number and type of valves in the line.

The space within 3 m of the stern manifold is to be considered as a dangerous space with regard to electrical or incendive equipment. *See also* M 1628.

**1115** Sounding pipes or other approved devices, which may permit a limited amount of vapour to escape to atmosphere when used, are to be provided at each tank to enable the liquid level to be ascertained. Separate ullage openings may be fitted as a reserve means. Arrangements which permit the escape of vapour are not to be fitted in enclosed spaces.

**1116** Provision is to be made for the gas freeing of the cargo oil tanks when the cargo has been discharged and for the ventilation and gas freeing of all compartments adjacent to cargo oil tanks.



## CARGO TANK VENTING ARRANGEMENTS

## General

1117 Cargo tank venting arrangements are to be designed to provide:—

- (a) Pressure/vacuum release of small volumes of vapour/air mixtures flowing during a normal voyage, and
- (b) Venting of large volumes of vapour/air mixtures during cargo handling and gas freeing operations.

## Plans

1118 A plan showing the arrangement of cargo tank vents indicating the type and position of the vent outlets from any superstructure, erection, air intake, etc., is to be submitted for approval.

## Pressure/Vacuum and Venting Systems

1119 The pressure/vacuum system and venting system may be separate or combined and are to comply with the following requirements where applicable.

1120 Venting systems may be designed to permit the free flow of vapour/air mixtures or, alternatively, the egress of vapour/air mixtures at velocities not less than 30 m/second. The requirements given later will vary depending on the system fitted.

1121 Vent and/or pressure/vacuum valve outlet pipes serving different tanks may be combined and led to a common main or be independent to each tank. For combined systems a means of isolation is to be provided between each cargo tank and the common main.

1122 Means are to be provided to prevent any tank being subjected to excessive pressure or vacuum during any phase of the cargo handling or ballasting operations.

1123 Pressure/vacuum valves are to be set at a positive pressure of not more than 0,02 N/mm<sup>2</sup> (0,2 kgf/cm<sup>2</sup>) above atmospheric and a negative pressure of not more than 0,007 N/mm<sup>2</sup> (0,07 kgf/cm<sup>2</sup>) below atmospheric. Higher positive pressures not exceeding 0,07 N/mm<sup>2</sup> (0,7 kgf/cm<sup>2</sup>) gauge may be permitted in specially designed integral tanks.

1124 The area of the venting system used during cargo loading is to be based on the maximum design loading rate and a gas evolution factor of 1,25.

1125 The only means of vapour escape and vacuum relief is to be through the approved system(s).

1126 Vent pipes and, where necessary, outlets from pressure vacuum valves are to be provided with readily renewable wire gauzes or safety heads of approved type. Material of wire gauzes is to be resistant to corrosion.

1127 Vapour/air mixtures escaping from pressure/vacuum valves and vent systems are to be arranged to discharge in an upward vertical direction; cowls, baffles, louvres, etc., are not to impair the free vertical flow. Suitable drainage arrangements are to be provided in vent pipes.

## LOCATION OF CARGO TANK VENTS

## General

1128 The following requirements for height and location of vents and pressure/vacuum valves are for non-boiling petroleum cargoes, i.e. cargoes which have a Reid vapour pressure less than atmospheric pressure.

## Pressure/Vacuum Valves

1129 Pressure/vacuum valve outlets are to be located at a height not less than 2,4 m above the deck and are not to be less than 9 m measured horizontally from any superstructure, erection, air intake, non-approved electrical equipment or any other possible source of ignition.

## Open Vents

1130 Cargo tank vents are to have a horizontal separation of at least 9 m from any superstructure, erection, air intake, non-approved electrical equipment or any other possible source of ignition, or the distances given in the following paragraphs, whichever is the greater.

1131 Vent pipes which permit the free flow of vapour/air mixture through open ends are to have a height of exit above the deck of  $H_1$  or  $H_2$ , except as controlled by  $L_1$ , depending on their proximity to, and the width of, any superstructure, erection, or structure having an air intake, non-approved electrical equipment or other possible source of ignition.

For distances greater than  $L_1$  and  $L_2$  measured from the superstructure or erection, the vent pipes are to have a height of  $H_1$  measured above the deck.

The height of  $H_2$  is based on a superstructure or erection height of 11 m. Should the height of this erection be other than 11 m, then  $H_2$  is to be corrected in direct proportion.



Values of  $H_1$ ,  $H_2$ ,  $L_1$  and  $L_2$  are to be determined as follows:

$$H_1 = 6,7 + \frac{d^{1,5}}{1050} \text{ m}$$

$$H_2 = 14,02 + \frac{d}{69,4} \text{ m}$$

$L_1$  = the distance to be measured from any erection 1,8 m or less in width, within which  $H_1$  heights are to be measured above the height of the erection at which the air intake, non-approved electrical equipment or other possible source of ignition exists,

$$L_1 = 4,57 + \frac{d}{18,9} \text{ m}$$

$L_2$  = the distance to be measured from any superstructure or erection more than 1,8 m in width, within which  $H_2$  heights are required,

$$L_2 = 8,84 + \frac{d^{2,68}}{1335 \times 10^2} \text{ m}$$

$d$  = diameter of open end of vent pipe, in mm.

Values of  $H_1$  and  $H_2$  heights, and  $L_1$  and  $L_2$  distances, determined by the above formulæ may be obtained from Fig. E 11.1. The value of  $H_2$  is based on a superstructure height of 11 m.

#### High Velocity Vents

1132 Where vent pipes are fitted with high velocity heads which expel the cargo vapours at a velocity not less than 30 m/second, the heads are to be of an approved design and their effectiveness demonstrated. The head outlet is to have a minimum height of 1,8 m above the deck and is not to be placed nearer than 9 m from a superstructure, erection, air intake, non-approved electrical equipment or other possible source of ignition.

#### Alternative Venting Arrangements

1133 Cargo tank venting arrangements other than those required by 1117 to 1132 will be specially considered.

For ships intended for the carriage of crude oil only, some relaxation in the foregoing requirements for tank venting arrangements may be permitted.

#### High Vapour Pressure Cargoes (Boiling)

1134 Special consideration will be required for venting arrangements where it is proposed to carry cargoes which have a Reid vapour pressure greater than atmospheric pressure.

#### Bilge, Ballast, Oil Fuel and other Piping Not Within the Cargo Handling System

1135 The pumping arrangements in the machinery space and at the forward end of the ship are to comply with the requirements for general cargo ships in so far as they are applicable and with the special requirements detailed in 1136 to 1140.

1136 A separate power pump is to be fitted in a suitable compartment forward of the cargo tanks to deal with bilge drainage, water ballast and oil fuel pumping at the fore end of the ship.

In small tankers, a forward power pump may be dispensed with, provided that suitable alternative arrangements are made, details of which are to be submitted.

1137 Where deep cofferdams can be filled with water ballast, a ballast pump in the main engine room may be used for emptying the after cofferdam, provided that the suction be led direct to the pump and not to an engine room pipe system. The ballast pump in the forward pump room may be used for emptying the forward cofferdam.

1138 Cofferdams are not to have any direct connections to the cargo oil tanks or cargo oil lines.

Where intended to be dry compartments, after cofferdams adjacent to the pump room may be drained by a cargo pump, provided that isolating arrangements are fitted in the bilge system as required by 1105; forward cofferdams may be drained by the bilge and ballast pump in the forward pump room. Alternatively, cofferdams may be drained by hand pumps or bilge ejectors.

Cofferdams are to be provided with sounding pipes and with air pipes led to the open. These air pipes are to be fitted with wire gauze diaphragms at their outlets.

1139 Bilge, ballast, oil fuel and other piping connected to the pumps at the ends of the ship are not to pass through the cargo oil tanks or have any connection with these tanks.

Cargo oil pipes are not to pass through ballast or oil fuel tanks, nor through compartments which are external to the cargo handling system.

1140 The oil fuel bunkering system is to be entirely separate from the cargo handling system.

#### Ballast Piping Within the Cargo Handling System

1141 Where ballast pipes are led from clean ballast pumps in the cargo oil pump room and pass through cargo oil tanks to forward ballast tanks, the pipes are to be of



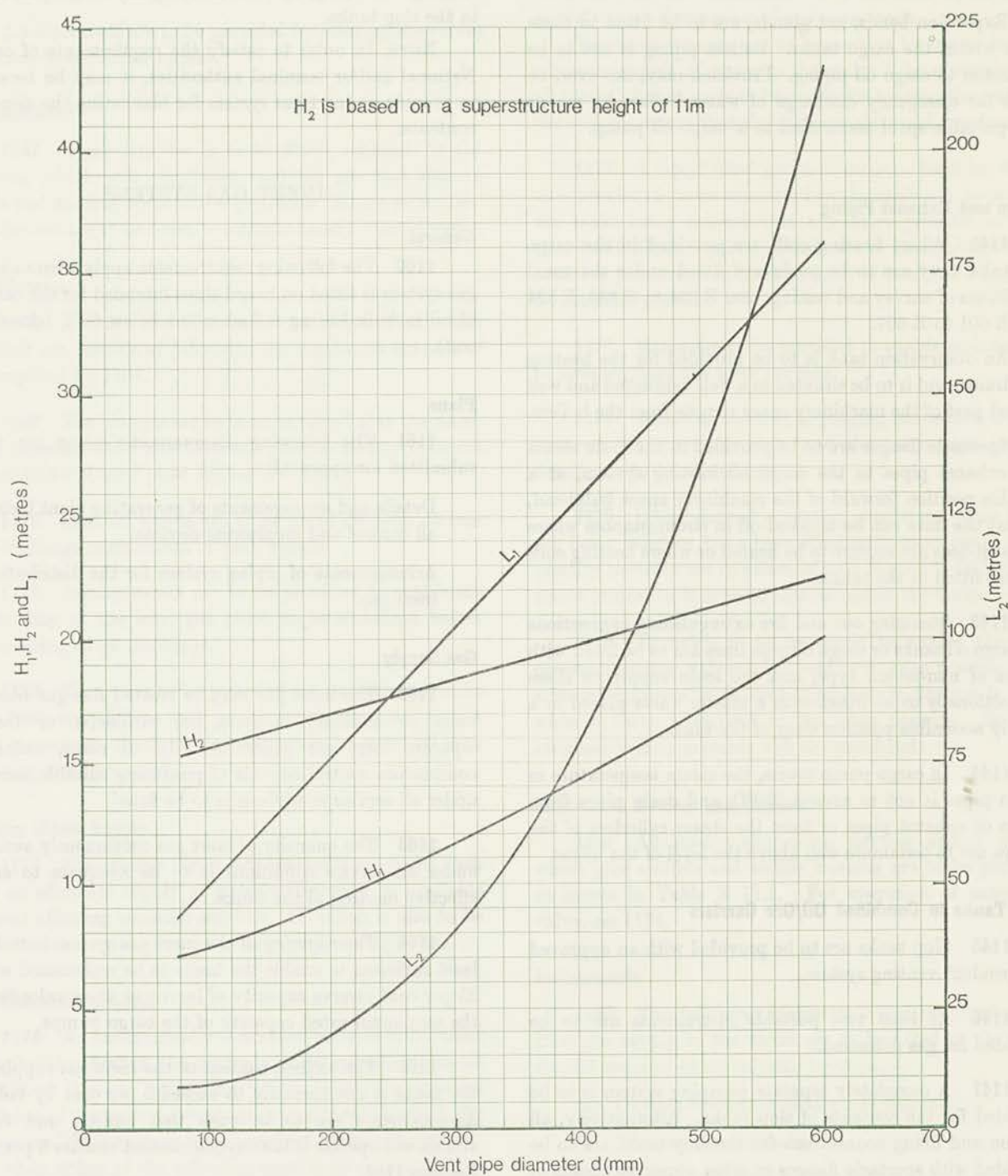


FIG. E 11.1 HEIGHT AND HORIZONTAL SEPARATION OF CARGO TANK VENTS

steel of substantial thickness, having welded or heavy flanged joints. The number of joints is to be kept to a minimum.

Expansion bends, not glands, are to be fitted to these pipes within the cargo tanks. Ballast piping is not to be connected to cargo oil piping. Provision may, however, be made for emergency discharge of water ballast by means of a portable spool connection to a cargo oil pump.

### Steam and Exhaust Piping

**1142** Where heating coils are provided in the cargo oil tanks, they are to be made and fitted under the usual conditions of survey and testing. *See* E 334 to E 336, E 524 and E 601 to E 607.

An observation tank is to be provided for the heating coil drains, and is to be situated in a well ventilated and well lighted part of the machinery space remote from the boilers.

Spectacle flanges are to be provided in the main steam and exhaust pipes to the cargo oil heating system, at a suitable position forward of the machinery space bulkhead, so that the lines can be blanked off in circumstances where cargo oil does not require to be heated or where heating coils are not fitted in the tanks.

**1143** Steaming out and fire extinguishing connections for cargo oil tanks or cargo oil pipe lines are to be fitted with valves of non-return type, and the main supply to these connections is to be fitted with a master valve placed in a readily accessible position clear of the tanks.

**1144** In cargo pump rooms, the steam temperature in steam pipes is not to exceed 250°C, and drain pipes from steam or exhaust pipes or from the steam cylinders of the pumps are to terminate well above the level of the bilges.

### Slop Tanks in Combined Oil/Ore Carriers

**1145** Slop tanks are to be provided with an approved independent venting system.

**1146** At least two portable instruments are to be provided for gas detection.

**1147** A completely separate pumping system is to be provided for the contents of slop tanks. Alternatively, all suction and filling connections for the slop tanks are to be provided with spectacle flanges or other approved means of isolation.

**1148** Adequate ventilation is to be provided for spaces surrounding slop tanks, *see* D 4010.

**1149** Warning notices are to be erected at suitable points detailing precautions to be observed prior to the ship loading, unloading, or when carrying dry cargo with liquid in the slop tanks.

NOTE. In order to satisfy the requirements of certain National and/or terminal authorities, it may be necessary to provide an inert gas system for blanketing the slop tank contents.

## INERT GAS SYSTEMS

### General

**1160** The following requirements apply where an inert gas system is fitted on board ships intended for the carriage of oil in bulk having a flash point below 60°C (closed cup test).

### Plans

**1161** The following diagrammatic plans are to be submitted for approval:

Details and arrangements of generating plant including all control and monitoring devices.

Arrangements of piping system for the distribution of inert gas.

### Gas Supply

**1162** The inert gas may be treated flue gas from the main or auxiliary boiler(s), gas turbine(s), or from a separate inert gas generator. In all cases, automatic combustion control capable of producing suitable inert gas under all service conditions is to be fitted.

**1163** The quantity of inert gas continuously available under all service conditions is to be adequate to ensure effective inerting of the tanks.

**1164** The capacity of the inert gas system is to be at least sufficient to enable the tanks to be replenished with a 25 per cent reserve capacity of inert gas when unloading at the maximum rated capacity of the cargo pumps.

**1165** The oxygen content of the inert gas supplied to the tanks is not normally to exceed 5 per cent by volume. Arrangements are to be such that audible and visible alarms will operate if the oxygen content reaches 8 per cent. *See also* 1181.

**1166** Shut-off valves, provided with indicators showing whether they are open or shut, are to be fitted in the outlet lines from the boiler uptakes to the gas scrubber.



Arrangements are to be made to ensure that the soot blowers are not operated when the corresponding shut-off valve is open.

Arrangements are to be provided for clearing the valves adjacent to the boiler uptake.

#### Gas Scrubber

**1167** A gas scrubber is to be fitted, adjacent to the blowers, which will effectively cool the gas and remove solids and sulphur combustion products. Filters or equivalent devices are to be fitted to minimize carry-over of water.

#### Gas Blowers

**1168** At least two blowers are to be provided which together are capable of delivering the maximum amount of gas required by 1164.

**1169** The blowers are to be so designed that the maximum pressure which can be exerted on the tank(s) does not exceed  $0,024 \text{ N/mm}^2$  ( $0,24 \text{ kgf/cm}^2$ ).

**1170** Shut-off valves are to be fitted on both suction and discharge connections of each blower.

**1171** Arrangements are to be provided to enable the functioning of the inert gas plant to be stabilized before commencing cargo discharge.

**1172** Means are to be provided for purging the tanks with fresh air. Where such means are incorporated in the inert gas system, the fresh air inlets are to be provided with blanking arrangements.

#### Cooling Water Supply

**1173** The cooling water arrangements are to be such that an adequate supply of water will always be available without affecting essential services. Provision is also to be made for a separate alternative supply of cooling water.

#### Gas Distribution Lines

**1174** An automatically controlled valve is to be fitted at the bulkhead where the gas main leaves the compartment containing the gas generating plant, or at the forward bulkhead of the most forward safe space through which the line passes. This valve is to be arranged to close automatically when either of the following conditions apply, *see also* 1181:—

- (a) Loss of cooling water pressure.
- (b) Blower failure.

**1175** Two approved non-return devices, one of which is to be a water seal, are to be fitted in the inert gas line on deck between the automatic valve required by 1174 and the aftermost connection of any cargo tank.

The arrangements are to be such as to ensure that an adequate supply of water to the seal will be maintained at all times. Provision is to be made for heating the water in the seal, to ensure that the seal is maintained free from ice.

**1176** A liquid filled pressure/vacuum breaking device or equivalent is to be connected to the gas main, to prevent the tanks being subjected to a positive pressure of more than  $0,024 \text{ N/mm}^2$  ( $0,24 \text{ kgf/cm}^2$ ) above atmospheric and a negative pressure of more than  $0,007 \text{ N/mm}^2$  ( $0,07 \text{ kgf/cm}^2$ ) below atmospheric.

**1177** Means are to be provided to enable each tank to be isolated from the inert gas line.

**1178** Where an inerting or purging connection is fitted between the inert gas main and the cargo pipe system, details are to be submitted.

**1179** Under normal operating conditions, when tanks are being filled or have been filled with inert gas, a small positive pressure not in excess of  $0,02 \text{ N/mm}^2$  ( $0,20 \text{ kgf/cm}^2$ ) above atmospheric is to be maintained in the tanks.

**1180** Provision is to be made to enable the tank pressure/vacuum valves to be held in an open position. The arrangements are to be such that clear indication is given when a valve is secured in the open position. Suitable alternative arrangements will be considered.

#### Shut-down Devices and Alarms

**1181** Automatic shut-down devices and/or alarms which give audible and visible warning are to be provided as shown in Table E 11.1. For operation of automatic valve, *see* 1174.

#### Instruments

**1182** The following instruments for monitoring the inert gas supply to the tanks are to be fitted in the cargo control room or other suitable location:—

- (a) Oxygen content indicator and recorder.
- (b) Temperature indicator.
- (c) Pressure indicator and recorder.

Portable instruments, suitable for measuring oxygen and hydrocarbon gases or vapour, and the necessary tank fittings are to be provided for monitoring the tank contents.

**Installation and Tests**

**1183** The inert gas system, including alarms and safety devices, is to be installed on board and tested under working conditions to the satisfaction of the Surveyors.

**Periodical Survey**

**1184** A periodical survey of the whole installation is to be carried out at intervals not exceeding 2 years.

The inert gas system, including alarms and safety devices, is to be tested to demonstrate that it is in good working condition to the satisfaction of the Surveyors.

**Cross-reference**

**1185** For cargo tank venting arrangements, see 1117 to 1149.

**TABLE E 11.1**

ITEM	ALARM	NOTE
Oxygen content of inert gas	High (8% by volume)	—
Temperature of inert gas	High	Automatic shut-down of blowers at predetermined high temperature
Pressure of inert gas	<i>Recommended settings</i> First low (200 mm of water pressure)  Second low (100 mm of water pressure)	First and second low alarms to be operated by independent pressure sensors fitted in the inert gas main on deck. A notice board is to be fitted at the control position stating that the cargo pumping rate is to be reduced at the second low alarm
Gas scrubber cooling water pressure or flow	Low	Automatic shut-down of blowers
Deck seal water supply pressure	Low	Alarm to operate at all times when the ship is not gas free
Deck seal water level	Low	Alarm arranged for operation when plant is not running
Automatic control system power supply	Failure	—



## Chapter F

# FIRE PROTECTION, DETECTION AND EXTINCTION

### PART 1

#### FIRE DETECTION AND EXTINCTION IN PASSENGER, CARGO AND OTHER SHIPS

##### Section 1

###### GENERAL

101 The requirements of Part 1 of this Chapter apply to passenger and cargo ships to be classed for unrestricted service.

102 While the requirements satisfy the regulations of the *International Convention for the Safety of Life at Sea, 1960*, attention should also be given to any relevant statutory requirements of the National Authority of the country in which the ship is to be registered. Compliance with these statutory requirements may be accepted as meeting the requirements of this Chapter.

103 Consideration will be given to special cases where the arrangements are equivalent to those required by these Rules. Consideration will also be given to fire extinguishing equipment and arrangements for small ships and ships to be classed for restricted or special service.

104 Fire fighting appliances—hoses, extinguishers, gas cylinders, emergency pumps, breathing apparatus, fireman's axe, etc.—which have been approved by a National Authority as complying with the regulations of the *International Convention for Safety of Life at Sea, 1960*, may be accepted as meeting the requirements of this Chapter.

105 Where it is proposed to apply centralized, bridge, or automatic controls to propulsion machinery and essential auxiliaries and it is intended that the engine and/or boiler rooms will not be continuously manned at sea, an approved fire detection system, in accordance with F 327 to F 329, is to be provided in these spaces (see Chapter L).

NEW PARA. 106 SEE NOTICE No. 2

NOTE. Having regard to the greater fire risk when a ship is in port, and the possibly reduced level of manning, it is recommended that an approved fire detection system, in accordance with F 327 to F 329, should be provided in engine and/or boiler rooms not fitted with the type of controls indicated in 105.

##### Section 2

###### PUMPS, WATER SERVICE PIPES, HYDRANTS AND HOSES

###### Total Capacity of Fire Pumps

201 In a passenger ship, the required fire pumps of F 4 are to be capable of delivering for fire fighting purposes a quantity of water not less than two-thirds of the total quantity required to be dealt with by the bilge pumps when employed for bilge pumping. See E 239 for number and capacity of bilge pumps.

The fire pumps are to be capable of developing the pressures in the fire main as required by 206.



202 In a cargo ship, the required fire pumps of F 5, other than the emergency pump (if any), are to be capable of delivering for fire fighting purposes a quantity of water not less than two-thirds of the total quantity required to be dealt with by the bilge pumps when employed for bilge pumping, except that in cargo ships the total required capacity of the fire pumps need not exceed 180 m<sup>3</sup> (180 tons) per hour. See E 235 for number and capacity of bilge pumps.

The fire pumps are to be capable of developing the pressures in the fire main as required by 206.

#### Fire Pumps

203 Sanitary, ballast, bilge or general service pumps may be accepted as fire pumps, provided that they are not normally used for pumping oil and that if they are subject to occasional duty for the transfer or pumping of fuel oil, suitable change-over arrangements are fitted.

In ships classed for navigation in ice, the fire pump sea inlet valves are to be provided with clearing arrangements as required by H 509 and H 511, or H 537, as applicable.

204 Any pump designated as a fire pump (other than any emergency pump required by F 505) is to have a capacity not less than 80 per cent of the total required capacity divided by the number of required fire pumps and in any event is to be capable of delivering at least the two required jets of water. Any deficiency in capacity of one of the fire pumps is to be made good by excess capacity of the other fire pumps. These fire pumps are to be capable of supplying the fire main system under the required conditions.

Where more pumps than required are installed their capacities will be specially considered.

205 Relief valves are to be provided in conjunction with all fire pumps if the pumps are capable of developing a pressure exceeding the design pressure of the water service pipes, hydrants and hoses. These valves are to be so placed and adjusted as to prevent excessive pressure in any part of the fire main system.

#### Pressure in the Fire Main

206 The fire pumps, associated piping and fire main are to be so designed that the following minimum pressures will be maintained at all hydrants under conditions where the two fire pumps required by 201 or 202 are simultaneously delivering water to the fire main of size required by 207 through adjacent nozzles of sizes required by 215.

#### PASSENGER SHIPS

4000 tons gross and over	...	0,32 N/mm <sup>2</sup> (3,2 kgf/cm <sup>2</sup> )
1000 tons gross and over but		0,28 N/mm <sup>2</sup> (2,8 kgf/cm <sup>2</sup> )
under 4000 tons gross		

Under 1000 tons gross	...	A pressure sufficient to produce a 12 m jet throw required by 215 to the satisfaction of the Surveyors.
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#### CARGO SHIPS

6000 tons gross and over	...	0,28 N/mm <sup>2</sup> (2,8 kgf/cm <sup>2</sup> )
1000 tons gross and over but		0,26 N/mm <sup>2</sup> (2,6 kgf/cm <sup>2</sup> )
under 6000 tons gross		
Under 1000 tons gross	...	A pressure sufficient to produce a 12 m jet throw required by 215 to the satisfaction of the Surveyors.

#### Fire Main

207 The diameter of the fire main is to be based on the required capacity of two fire pumps and the diameters of the water service pipes are to be sufficient to ensure an adequate supply of water for the simultaneous operation of at least two fire hoses. In general, the diameter of the fire main should not be less than that required by the following formula but is in no case to be less than 50 mm:—

$$d = \frac{L}{1,2} + 25 \text{ mm}$$

where d = internal diameter of the fire main, in mm,

L = Rule length of the ship, in metres.

The diameter of the fire main need not exceed 125 mm in cargo ships and 180 mm in passenger ships.

208 The fire main is to be situated outside the machinery spaces and the discharge line or lines from the fire pumps are to be fitted with isolating valves at the connections to the fire main. Where the machinery space is situated amidships isolating valves are also to be provided in the fire main so that the hydrants at both ends of the ship may be used simultaneously or separately.

209 The wash deck line may be used as a fire main provided the requirements of this Section are satisfied.

210 All water pipes for fire extinguishing are to be provided with drain valves for use in frosty weather. The valves are to be located where they will not be damaged by cargo.

#### Number and Position of Hydrants

211 The number and position of the hydrants are to be such that at least two jets of water not emanating from the same hydrant, one of which is to be from a single length



of hose, may reach any part of the ship. In ships of 1000 tons gross and over two hydrants are to be provided in the machinery spaces: in smaller ships one hydrant will be accepted.

### Pipes and Hydrants

**212** Materials readily rendered ineffective by heat are not to be used for fire mains. Where steel pipes are used they are to be galvanized internally and externally. Cast iron pipes are not acceptable. The pipes and hydrants are to be so placed that the fire hoses may be easily coupled to them. In ships where deck cargo may be carried, the positions of the hydrants are to be such that they are always readily accessible and the pipes are to be arranged as far as practicable to avoid risk of damage by such cargo. Unless there is provided one hose and nozzle for each hydrant in the ship there shall be complete interchangeability of hose couplings and nozzles.

**213** Valves or cocks are to be fitted in such positions on the pipes that any of the fire hoses may be removed while the fire pumps are at work.

### Fire Hoses

**214** Fire hoses are to be of seamless hemp, close weave flax canvas, or other approved material. The hoses are to be sufficient in length to project a jet of water to any of the spaces in which they may be required to be used. Their length in general is not to exceed 18 m. Each hose is to be provided with a nozzle and the necessary couplings. Fire hoses, together with any necessary fittings and tools, are to be kept ready for use in conspicuous positions near the water service hydrants or connections.

### Nozzles

**215** The nozzles used for extinguishing fires other than oil fires are to have a bore of not less than 12 mm. For accommodation and service spaces, a nozzle size of 12 mm will normally be adequate but for machinery spaces and exterior locations 12, 16 or 19 mm nozzles may be adopted so as to make full use of the maximum discharge capacity of the fire pumps. The jet throw at any nozzle is to be about 12 m. Dual purpose nozzles for jet or fog may be adopted.

*SUB PARA ADDED - SEE NOTICE No. 2*

### International Shore Connection

**216** The international shore connection required by F 408 and F 509 is to be suitable for a working pressure of  $1,03 \text{ N/mm}^2$  ( $10,5 \text{ kgf/cm}^2$ ). It is to have on one side a flat faced flange with dimensions as shown in Fig. F 2.1, and on the other side a permanently attached coupling that will

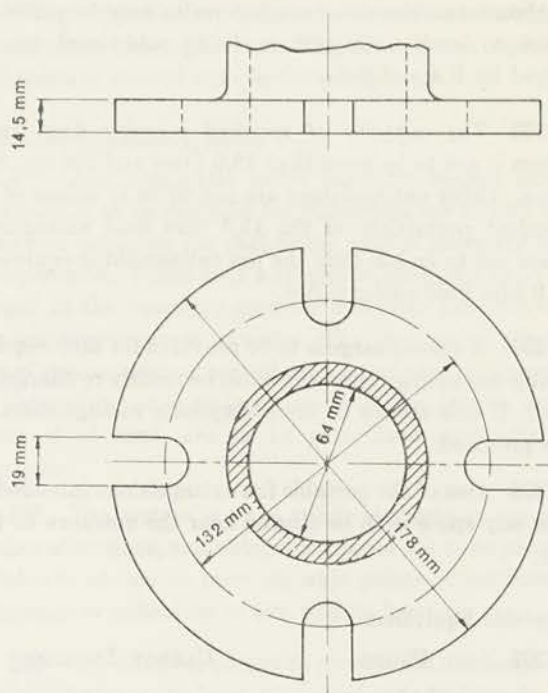


Fig. F 2.1

fit the ship's hydrants and hose. The connection is to be kept aboard the ship together with a gasket suitable for  $1,03 \text{ N/mm}^2$  ( $10,5 \text{ kgf/cm}^2$ ) service, together with four 16 mm bolts, 50 mm in length, and eight washers.

## Section 3

### FIRE EXTINGUISHERS AND EXTINGUISHING SYSTEMS

#### Fire Extinguishers (Portable and Non-portable)

**301** All fire extinguishers are to be approved types.

If considered necessary, the Committee may require the makers to produce evidence from a recognized independent testing authority regarding the suitability of their appliances.

**302** The extinguishers required for use in the machinery spaces of ships burning oil as fuel are to be of a type discharging froth, carbon dioxide gas, dry powder, or other approved medium suitable for extinguishing oil fires.

Fire extinguishers containing an extinguishing medium which either itself or when in use gives off gases harmful to persons are not to be used. For radio rooms and switchboards extinguishers containing not more than 1,136 litres



of carbon tetrachloride or similar media may be permitted subject to such extinguishers being additional to any required by F 4 and F 5.

**303** The capacity of required portable fluid extinguishers is not to be more than 13,5 litres and not less than 9 litres. Other extinguishers are not to be in excess of the equivalent portability of the 13,5 litre fluid extinguisher and are not to be less than the fire extinguishing equivalent of a 9 litre fluid extinguisher.

**304** A spare charge is to be provided for each required portable fire extinguisher which can be readily re-charged on board. If this cannot be done, duplicate extinguishers are to be provided.

**305** One of the portable fire extinguishers intended for use in any space is to be stowed near the entrance to that space.

#### Acceptable Equivalents

306	FROTH	CARBON DIOXIDE
	136 litres	45 kg
	45 litres	16 kg
	Portable	4,5 kg

#### Fire-smothering Gas or Steam for Machinery and Cargo Spaces

**307** Where provision is made for the injection of gas into machinery spaces or gas or steam into cargo spaces for fire extinguishing purposes, the necessary pipes for conveying the gas or steam are to be provided with control valves or cocks which are to be so placed that they will be easily accessible and not readily cut off from use by an outbreak of fire. These control valves or cocks are to be so marked as to indicate clearly the compartments to which the pipes are led. Suitable provision is to be made to prevent inadvertent admission of the gas or steam to any compartment. Where cargo spaces, fitted with smothering equipment for fire protection, are used as passenger spaces the smothering connections are to be blanked during service as a passenger space. Blank flanges fitted in gas or steam distribution pipes are to be of the "spectacle" type. The nuts for the securing bolts are to be of non-corrodible metal.

**308** The piping is to be of adequate size and so arranged to provide effective distribution of fire-smothering gas or steam. In holds exceeding 18 m in length, there are to be at least two pipes, one of which is to be fitted in the forward part and one in the after part; the steam pipes are to be led well down in the space as remote as possible from the shell. Separate pipes are to be provided for lower hold and

'tween decks. All pipes are to be arranged to be self-draining and are not to be led through refrigerated spaces unless the pipes are specially insulated. Steel distribution pipes are to be galvanized internally and externally and are not to be smaller than 19 mm bore for carbon dioxide and 25 mm bore for steam and inert gas.

*2nd Sub-Para - See Notice No 2*  
In tankers, the piping system is to be so arranged that the gas or steam will be distributed over the surface of the cargo. See also F 513.

#### Carbon Dioxide Gas

**309** When carbon dioxide is used as the extinguishing medium in cargo spaces, the quantity of gas available is to be sufficient to give a minimum volume of free gas equal to 30 per cent of the gross volume of the largest cargo compartment in the ship which is capable of being sealed.

**310** When carbon dioxide is used as an extinguishing medium for spaces containing boilers or internal combustion type machinery, the quantity of gas carried is to be sufficient to give a minimum volume of free gas equal to the larger of the following, either:—

- (1) 40 per cent of the gross volume of the largest space, the volume to include the casing up to the level at which the horizontal area of the casing is 40 per cent or less of that of the space concerned; or
- (2) 35 per cent of the entire volume of the largest space including the casing;

provided that the above mentioned percentages may be reduced to 35 per cent and 30 per cent respectively for cargo ships of less than 2000 tons gross; provided also that if two or more spaces containing boilers or internal combustion type machinery are not entirely separate they are to be considered as forming one compartment.

When evaluating the quantity of carbon dioxide gas required for the machinery spaces of motor ships, the free air content of the main starting air receivers is to be added to the above gross space volumes. See also J 640.

**311** When carbon dioxide is used as an extinguishing medium both for cargo spaces and for spaces containing boilers or internal combustion type machinery the quantity of gas need not be more than the maximum required either for the largest cargo compartment or machinery space. The volume of gas is to be calculated at 0,56 m<sup>3</sup>/kg.

**312** When carbon dioxide is used as the extinguishing medium for spaces containing boilers or internal combustion type machinery the fixed piping system is to be such that 85 per cent of the gas can be discharged into the space within 2 minutes.



**313** The gas cylinders and main controls are to be located to the Surveyors' satisfaction in a cool and well ventilated position, not likely to be made inaccessible by fire. Provision is to be made for changing the cylinders and checking their contents by weighing or other approved means. Operating instructions are to be displayed at the controls.

#### Inert Gas

**314** Where a generator producing inert gas is used to provide smothering gas in a fixed fire-smothering installation for cargo spaces, it is to be capable of producing hourly a volume of free gas at least equal to 25 per cent of the gross volume of the largest compartment protected in this way for a period of 72 hours. The generator is to be located in a position not likely to be made inaccessible by fire.

2ND SUB-PARA - SEE NOTICE No. 2

#### Steam

**315** When steam is used as the extinguishing medium in cargo spaces the boiler or boilers available for supplying steam are to have an evaporation of at least 1,0 kg of steam per hour for each 0,75 m<sup>3</sup> of the gross volume of the largest cargo compartment in the ship. It is required that steam will be available immediately and will not be dependent on the lighting of boilers, that it can be supplied continuously until the end of the voyage in the required quantity (in addition to any steam necessary for the normal requirements of the ship including propulsion) and that provision is made for extra feed water necessary to meet this requirement.

Steam is not to be used in spaces containing explosives.

Steam used for fire extinguishing purposes is not to be obtained from a supply of superheated steam.

#### Audible Alarms

**316** Means are to be provided whereby audible warning is given automatically before fire-smothering gas can be released into the machinery space and any other working space.

**317** The audible alarms fitted in cargo pump rooms of ships intended for the carriage of cargo oil having a flash point below 60°C (closed cup test), to warn of the release of extinguishing medium in such spaces, may be of the pneumatic or electrical type.

Where pneumatically operated alarms are fitted which require periodic testing, carbon dioxide is not to be used as an operating medium. Air operated alarms may be used provided the air supply is clean and dry.

Where electrically operated alarms are used, the arrangements are to be such that the electric operating mechanism is located outside the pump room.

#### Automatic Sprinkler Systems

**318** Any automatic water sprinkler system for fire protection is to be designed for immediate use at any time, so that no action on the part of the crew is necessary to set it in operation. Where such a system is fitted, it is to be kept charged at the necessary pressure and is to have provision for a continuous supply of water. The distribution pipes are to be of steel or other approved material of adequate strength and the mains and their branches up to the section control points, if of steel, are to be galvanized internally and externally.

**319** The system is to be subdivided into an approved number of sections, and automatic alarms are to be provided to indicate at one or more suitable points or stations the occurrence or indication of fire, and its location.

**320** The pump or pumps to provide the discharge from sprinkler heads are to be so connected as to be brought into action automatically by a pressure drop in the system. There is to be a connection from the ship's fire main provided with a lockable screw-down valve and a non-return valve.

**321** Each pump is to be capable of maintaining a sufficient supply of water at the appropriate pressure, at the sprinkler heads, while such number of sprinkler heads as may be approved are in operation.

**322** In passenger ships there are not to be less than two sources of power supply for the sea water pumps, air compressors and automatic alarms. Where the sources of power are electrical, these are to be a main generator and an emergency source of power. One supply is to be taken from the main switchboard by separate feeders reserved solely for that purpose. Such feeders are to be run to a change-over switch situated near to the sprinkler unit and the switch shall normally be kept closed to the feeder from the emergency switchboard. The change-over switch is to be clearly labelled, and no other switch except those at the switchboards is to be permitted in these feeders.

**323** Sprinkler heads are required to operate at temperatures between 68°C and 93°C except in drying rooms and other hot spaces. Suitable means for the periodic testing of all automatic arrangements are to be provided.

**324** Where a sprinkler system of fire protection is employed in a ship the superstructure of which is constructed in aluminium alloy, the whole unit including the sprinkler pump, tank and air compressor is to be situated in an



approved position reasonably remote from the boiler and machinery spaces. If the feeders from the emergency generator to the sprinkler unit pass through any space constituting a fire risk the cables are to be of a fireproof type.

#### Fixed Froth Fire Extinguishing System

325 Any required fixed froth fire extinguishing system is to be able to discharge a quantity of froth sufficient to cover to a depth of 150 mm the largest area over which oil fuel is liable to spread.

326 Such a system is to be controlled from an easily accessible position or positions, outside the space to be protected, which will not be readily cut off by an outbreak of fire. The distribution pipes are to be of steel galvanized internally and externally.

#### Fire Detection Systems

327 All required fire detection systems are to be capable of automatically indicating the presence or indication of fire and its location. Indicators are to be centralized either on the bridge or in other control stations which are provided with a direct communication with the bridge. The indicators may be distributed among several stations subject to approval by the Surveyors.

328 Electrical equipment used in the operation of required fire detection systems is to have two separate sources of power, one of which should be an emergency source.

329 The alarm system is to operate both audible and visible signals at the main stations referred to in 327. Detection systems for cargo spaces need not have audible alarms. Where it is intended that the engine and/or boiler rooms will not be continuously manned at sea, the alarm system is to operate both audible and visible signals at the station from which the machinery is controlled, which should be in direct communication with the bridge. When control is effected from the bridge only, the alarms must operate also in the Engineer Officers' accommodation.

#### Fixed Pressure Water-spraying Systems for Engine Rooms and Boiler Rooms

330 Fixed pressure water-spraying systems for boiler rooms with oil fired boilers and engine rooms with internal combustion type machinery are to be provided with spraying nozzles of an approved type.

331 The number and arrangement of the nozzles are to be to the satisfaction of the Surveyors and be such as to ensure an effective distribution of water in the spaces to be

protected. Nozzles are to be fitted above bilges, tank tops and other areas over which oil fuel is liable to spread and also above oil fuel settling and service tanks, heaters, pumping units, purifiers and other main fire hazards in the boiler and engine rooms.

332 The system may be divided into sections, the distribution manifolds of which are to be operated from easily accessible positions outside the spaces to be protected and which will not be readily cut off by an outbreak of fire.

333 The system is to be kept charged at the necessary pressure and the pump supplying the water for the system is to be put automatically into action by a pressure drop in the system.

334 The pump is to be capable of simultaneously supplying at the necessary pressure all sections of the system in any one compartment to be protected. The pump and its controls are to be installed outside the space or spaces to be protected. It is not to be possible for a fire in the space or spaces protected by the water-spraying system to put the system out of action.

335 Special precautions are to be taken to prevent the nozzles from becoming clogged by impurities in the water or corrosion of piping, nozzles, valves and pump.

#### Fireman's Outfit

336 A fireman's outfit is to consist of a breathing apparatus, a lifeline, a safety lamp and an axe, as described in this paragraph.

The breathing apparatus is to be of an approved type and may be either (1) or (2):—

- (1) A smoke helmet or smoke mask which is to be provided with a suitable air pump and a length of air hose sufficient to reach from the open deck, well clear of hatch or doorway, to any part of the holds or machinery spaces. If, in order to comply with this requirement, an air hose exceeding 36,5 m in length would be necessary, a self-contained breathing apparatus is to be substituted or provided in addition.
- (2) A self-contained breathing apparatus which is to be capable of functioning for a period of at least 30 minutes. Spare bottles are to be provided except where facilities for re-charging the bottles are available on board ship.

Each breathing apparatus is to have attached to its belt or harness, by means of a snaphook, a fireproof lifeline of sufficient length and strength.



The safety lamp (hand lantern) is to be of an approved type. Such safety lamps are to be electric, and are to have a minimum burning period of 3 hours.

The axe is to have an insulated handle.

#### Closing of Openings and Control of Fans

337 Provision is to be made for closing all openings which might admit air to machinery spaces, to other spaces where there is risk of an oil fire and to cargo spaces protected by fire-smothering systems. Skylights and ventilators of machinery spaces including pump rooms in tankers are to be capable of being shut from deck or from a safe position outside these spaces. Provision is to be made for rapidly stopping all fans from positions outside such spaces.

#### Cross-references

338 For precautionary arrangements relating to oil leakage and outbreaks of fire, *see*:—

D 1927–D 1930, D 2113, D 2645, E 310, E 315–E 319, E 330–E 333, E 337–E 343, E 403–E 405, E 407, E 413–E 414, E 912 and E 1109.

### Section 4

#### REQUIREMENTS FOR PASSENGER SHIPS

##### Fire Detection and Alarms

401 Manual fire alarms are to be fitted throughout the passenger and crew accommodation to enable the fire patrol to give an alarm immediately to the bridge or fire control station.

402 A fire alarm or fire detecting system is to be provided which will automatically indicate at one or more suitable points or stations, where it can be most quickly observed by officers and crew, the presence or indication of fire and its location in any parts of the ship such as cargo spaces, baggage and store rooms which are not accessible to the patrol system, except where the ship is engaged on voyages of such short duration that it would be unreasonable to apply this requirement.

##### Fire Pumps and Water Service Pipes

403 A passenger ship is to be provided with fire pumps, water service pipes, hydrants and hoses complying with F 2 and with the following requirements:—

- (1) A passenger ship of 4000 tons gross and over is to be provided with at least three independently driven

fire pumps and every passenger ship of less than 4000 tons gross with at least two such fire pumps.

- (2) In a passenger ship of 1000 tons gross and over the arrangement of sea connections, pumps and sources of power for operating them is to be such as to ensure that a fire in any one compartment will not put all the fire pumps out of action.
- (3) In a passenger ship of less than 1000 tons gross, if a fire in any one compartment could put all the pumps out of action, an emergency fire pump having a capacity of not less than 15 m<sup>3</sup> per hour is to be provided.

##### Fire Hydrants, Hoses and Nozzles

404 A passenger ship is to be provided with such number of fire hoses as are appropriate and sufficient for the type of ship. There is to be at least one fire hose for each of the hydrants required by F 211, and these hoses are to be used only for the purposes of extinguishing fires or testing the fire extinguishing apparatus at fire drills and surveys.

405 In accommodation, service and machinery spaces, the number and position of hydrants are to be such that the requirements of F 211 may be complied with when all watertight doors and all doors in main vertical zone fire bulkheads are closed.

406 In a passenger ship the arrangements are to be such that at least two jets of water can reach any part of any cargo space when empty.

407 All hydrants in the machinery spaces of passenger ships with oil-fired boilers, steam turbine or internal combustion type propelling machinery are to be fitted with hoses having in addition to the nozzles required in F 215 nozzles suitable for spraying water on oil, or alternatively, dual purpose nozzles. One such hydrant is to be provided in the shaft tunnel adjacent to the engine room watertight door.

##### International Shore Connection

408 A passenger ship of 1000 tons gross and over is to be provided with at least one international shore connection, complying with F 216. Facilities are to be available enabling such a connection to be used on either side of the ship.

##### Portable Fire Extinguishers in Accommodation and Service Spaces

409 A passenger ship is to be provided in accommodation, radio rooms and service spaces with such approved portable fire extinguishers as the Surveyors may deem to be



appropriate and sufficient. In galleys and their sub-division, one or more portable extinguishers suitable for dealing with fires in oil-fired or electric cooking equipment are to be provided.

#### Fixed Fire-smothering Arrangements in Cargo Spaces

410 The cargo spaces of passenger ships of 1000 tons gross and over are to be protected by a fixed fire-smothering gas system complying with F 3.

411 Where a passenger ship is engaged on voyages of such short duration that it would be unreasonable to apply the requirements of 410 and also in passenger ships of less than 1000 tons gross, the necessity for fire-smothering arrangements in cargo spaces will be specially considered.

#### Fire Extinguishing Appliances in Boiler Rooms, etc.

412 In spaces where main or auxiliary oil-fired boilers are situated, or in spaces containing oil fuel units or settling tanks, a passenger ship is to be provided with any one of the following fixed fire extinguishing installations complying with F 3:—

- (1) A pressure water-spraying system.
- (2) A fire-smothering gas installation.
- (3) A fixed froth installation supplemented, if necessary, by a fixed or mobile arrangement for pressure water- or froth-spraying to fight fire above the floor plates.

In each case if the engine and boiler rooms are not entirely separate, or if fuel oil can drain from the boiler room into the engine room bilges, the combined engine and boiler rooms are to be considered as one compartment.

413 There are to be at least two approved portable extinguishers discharging froth or other approved medium suitable for extinguishing oil fires, in each firing space in each boiler room and each space in which a part of the oil fuel installation is situated.

There is not to be less than one approved froth type extinguisher of at least 136 litres capacity or equivalent in each boiler room. These extinguishers are to be provided with hoses on reels suitable for reaching any part of the boiler room and spaces containing any part of the oil fuel installations.

414 In each firing space there is to be a receptacle containing at least 0,28 m<sup>3</sup> of sand, sawdust impregnated with soda or other approved dry material and a scoop for distributing this material. Alternatively, an approved portable extinguisher may be substituted therefor.

#### Fire Fighting Appliances in Spaces containing Internal Combustion Type Machinery

415 Where internal combustion engines or gas turbines are used, either (1) for main propulsion or (2) for auxiliary purposes associated with a total power not less than 746 kW, a passenger ship is to be provided with the following arrangements A and B:—

- (A) There is to be one of the fixed arrangements 1, 2 or 3 required by 412.
- (B) There is to be in each engine space one approved froth type extinguisher of not less than 45 litres capacity or equivalent and also one approved portable froth type extinguisher for each 746 kW of the engines or part thereof; but the total number of portable extinguishers so supplied is not to be less than two and need not exceed six.

#### Fire Fighting Arrangements in Spaces containing Steam Machinery

416 Provision is to be made for extinguishing lubricating oil fires in spaces which are separated from boiler rooms by watertight bulkheads when these spaces contain steam turbines or enclosed forced lubricated steam engines using superheated steam. Equipment not less effective than detailed in 415 (B) is to be provided to the Surveyors' satisfaction.

#### Fireman's Outfits

417 A passenger ship is to carry at least two fireman's outfits each complying with the requirements of F 336. Where the ship exceeds 10 000 tons gross at least three outfits are to be carried and where it exceeds 20 000 tons gross at least four outfits are to be carried. These outfits are to be kept in widely separated places ready for use.

### Section 5

#### REQUIREMENTS FOR CARGO SHIPS

##### Fire Pumps and Water Service Pipes

501 All cargo ships are to be provided with fire pumps, water service pipes, hydrants and hoses complying in general with F 2.

502 In cargo ships of less than 150 tons gross, one power pump is to be available for fire extinguishing service.



If the ship has a restricted class for harbour or river service a suitable hand pump may be substituted for the power pump.

**503** In cargo ships of 150 tons gross and over, but less than 1000 tons gross, not less than two power pumps are to be provided, one of which is to be an independent pump.

**504** In cargo ships of 1000 tons gross and over not less than two independently driven power pumps are to be provided.

**505** In a cargo ship of 1000 tons gross and over if a fire in any one compartment could put all the pumps out of action there is to be an alternative means of providing water for fire fighting. This alternative means is to be a fixed emergency pump independently driven by a compression ignition engine, or other approved means and having a capacity of not less than 15 m<sup>3</sup> per hour in ships of 1000 tons gross to 2000 tons gross, and not less than 25 m<sup>3</sup> per hour for ships above 2000 tons gross. This emergency pump is to be capable of supplying two jets of water to the satisfaction of the Surveyors. The pump should be located remote from the machinery space, e.g. in ships with machinery amidships the pump should be installed in the tunnel or steering gear compartment, and in ships with machinery aft the pump preferably should be located forward. The pump is to be provided with its own sea suction and a discharge to the fire main. The suction lift is not to exceed 6 m with the ship in light draught. The fuel service tank for the engine is to have a capacity for at least 3 hours operation of the emergency pump. In addition sufficient fuel is to be available for at least 12 hours operation of this pump.

#### Fire Hydrants, Hoses and Nozzles

**506** In cargo ships the number of fire hoses to be provided, each complete with couplings and nozzles, is to be one for each 30 m length of the ship and one spare, but in no case less than five in all for cargo ships of 1000 tons gross and over and three in all for smaller ships. These numbers do not include any hoses required in any engine or boiler room. If necessary the number of hoses is to be increased so as to ensure that hoses in sufficient number are available and accessible at all times, having regard to the type of the ship and the nature of the trade on which the ship is employed.

**507** In accommodation, service and machinery spaces, the number and position of hydrants are to be such as to comply with the requirements of F 211. In a cargo ship the arrangements are to be such that at least two jets of water can reach any part of any cargo space when empty.

In ships of 2000 tons gross and over a hydrant is to be provided in the shaft tunnel adjacent to the engine room watertight door.

**508** All hydrants in the machinery spaces of cargo ships with oil fired boilers or internal combustion type propelling machinery are to be fitted with hoses having in addition to the nozzles required in F 215 nozzles suitable for spraying water on oil, or alternatively, dual purpose nozzles.

#### International Shore Connection

**509** A cargo ship of 1000 tons gross and over is to be provided with at least one international shore connection, complying with F 216. Facilities are to be available enabling such a connection to be used on either side of the ship.

#### Portable Fire Extinguishers in Accommodation and Service Spaces

**510** A cargo ship is to be provided in accommodation, radio rooms and service spaces with a sufficient number of portable fire extinguishers to ensure that at least one extinguisher will be readily available for use in every compartment of the crew and passenger spaces to the Surveyors' satisfaction; in any case, their number is not to be less than five for ships of 1000 tons gross and over and not less than three in ships of under 1000 tons gross.

For galleys and for spaces containing domestic boilers one portable fire extinguisher suitable for dealing with oil fires or fires in electric cooking equipment is to be provided.

Where a sprinkler system is installed the arrangements will be specially considered.

#### Fixed Fire-smothering Arrangements in Cargo Spaces

**511** Cargo spaces of ships of 2000 tons gross and over are to be protected by a fixed fire-smothering system using carbon dioxide, inert gas or steam. The arrangements are to comply with F 3.

**512** The requirements of 511 may be waived for the cargo holds of any ship (other than the tanks of a tanker):—

- (1) If they are provided with steel hatch covers having fireproof joints and effective means of closing all ventilators and other openings leading to the holds; or
- (2) if the ship is constructed and intended solely for carrying such cargoes as ore, coal or grain; or
- (3) where the ship is engaged on voyages of such short duration that it would be unreasonable to apply the requirement.



DELETED  
SEE NOTICE No.2

513 The cargo tanks of tankers of 500 tons gross and over are to be protected by a fixed fire-smothering system using carbon dioxide, steam or froth. Installations discharging froth externally to the tanks may be accepted. The details of such installations are to be to the satisfaction of the Surveyors (for steam system see E 1143).

513

~~514~~ The cargo tanks of liquefied gas carriers are to be protected by a fixed fire-smothering gas system and/or dry chemical extinguishing system. Details are to be submitted for approval.

NEW PARAS ADDED 514-526  
SEE NOTICE No.2

#### Fire Detection in Cargo Spaces

527 A smoke or fire detection system is to be provided in each cargo space containing explosives and in adjacent cargo spaces.

#### Fire Extinguishing Appliances in Boiler Rooms, etc.

528 In spaces where main or auxiliary oil-fired boilers are situated, or in spaces containing oil fuel units or settling tanks, a cargo ship is to be provided with any one of the following fixed fire extinguishing installations complying with F 3.

- (1) A pressure water-spraying system.
- (2) A fire-smothering gas installation.
- (3) A fixed froth installation supplemented, if necessary, by a fixed or mobile arrangement for pressure water- or froth-spraying to fight fire above the floor plates.

The fixed installation is to be of type (2) above in all cases where the flash point of the oil fuel is less than 60°C (closed cup test) or where methane gas is used as a fuel for the propulsion of methane tankers.

In each case if the engine and boiler rooms are not entirely separate, or if fuel oil can drain from the boiler room into the engine room bilges, the combined engine and boiler rooms are to be considered as one compartment.

529 ~~526~~ There are to be at least two approved portable extinguishers discharging froth or other approved medium suitable for extinguishing oil fires in each firing space in each boiler room and each space in which a part of the oil fuel installation is situated. In addition, there is to be at least one extinguisher of the same description with a capacity of 9 litres for each burner, provided that the total capacity of the additional extinguisher or extinguishers need not exceed 45 litres for any one boiler room.

F 513 - F 522

530

~~529~~ In each firing space there is to be a receptacle containing at least 0,28 m<sup>3</sup> of sand, sawdust impregnated with soda, or other approved dry material and a scoop for distributing this material. Alternatively, an approved portable extinguisher may be substituted therefor.

#### Fire Fighting Appliances in Spaces containing Internal Combustion Type Machinery

531 ~~528~~ Where internal combustion engines or gas turbines are used, either (1) for main propulsion machinery, or (2) for auxiliary purposes associated with a total power not less than 746 kW, a cargo ship of 1000 tons gross and over is to be provided with the following arrangements A and B, and a cargo ship of under 1000 tons gross with arrangement B. For cargo ships of under 150 tons gross the provision of a 45 litre extinguisher may be waived.

- (A) There is to be one of the fixed arrangements 1, 2 or 3 required by 516.
- (B) There is to be in each engine space one approved froth type extinguisher of not less than 45 litres capacity or equivalent and also one approved portable froth extinguisher for each 746 kW of the engines or part thereof; but the total number of portable extinguishers so supplied is not to be less than two and need not exceed six.

#### Fire Fighting Arrangements in Spaces containing Steam Machinery

532 ~~527~~ Provision is to be made for extinguishing lubricating oil fires in spaces which are separated from boiler rooms by watertight bulkheads when these spaces contain propulsion turbines or enclosed forced lubricated engines using superheated steam. Equipment not less effective than detailed in arrangement B of 519 is to be provided to the Surveyors' satisfaction.

#### Fire Fighting Arrangements in Pump Rooms and Compressor Rooms of Tankers

533 ~~526~~ The cargo pump rooms in tankers of 500 tons gross and over are to be provided with a fixed, deck operated, fire extinguishing system using steam, water spray, carbon dioxide or other suitable medium. ~~LIQUEFIED GAS CARRIERS~~

In addition, two portable foam extinguishers or equivalent are to be provided, one at the pumps and one at the pump room entrance.

534 ~~527~~ The cargo pump rooms and compressor rooms in liquefied gas carriers of 500 tons gross and over are to be provided with a fixed remote controlled fire extinguishing system using carbon dioxide or other suitable medium. ~~AMENDED SEE NOTICE No.2~~



In addition, two portable dry chemical extinguishers or equivalent are to be provided in each space.

~~535 522~~ In tankers and liquefied gas carriers of less than 500 tons gross the fire extinguishing arrangements are to be to the satisfaction of the Surveyors.

#### Fireman's Outfits

~~536 521~~ - See Notice No. 2

A cargo ship is to carry at least one fireman's outfit complying with the requirements of F 336. Ships of 4000 tons gross and over are to carry two such outfits which are to be located at widely separated positions.

### Section 6

#### REQUIREMENTS FOR SHIPS NOT FITTED WITH PROPELLING MACHINERY

601 A power pump or hand pump is to be fitted having a suction from the sea and a discharge to deck for fire extinguishing purposes.

Where oil fuel is used for the generation of power, fire extinguishing appliances suitable for fighting oil fires are to be provided to the satisfaction of the Surveyors.

## PART 2

## FIRE PROTECTION IN PASSENGER, CARGO AND OTHER SHIPS

## Section 7

## GENERAL

OF THIS SECTION  
AMENDED SEE  
NOTICE No. 2

701 Except where otherwise stated, the requirements of Part 2 of this Chapter apply to passenger ships ~~carrying more than 36 passengers~~ and cargo ships ~~of 1000 tons gross and over~~ to be classed for unrestricted service.

702 While the requirements satisfy the regulations of the *International Convention for the Safety of Life at Sea, 1960*, attention should also be given to any relevant statutory requirements of the National Authority of the country in which the ship is to be registered. Compliance with these statutory requirements may be accepted as meeting the requirements of this Chapter.

703 Consideration will be given to special cases where the arrangements are equivalent to those required by these Rules. Consideration will also be given to fire protection arrangements in ships to be classed for restricted or special services.

704 Plans showing the proposed arrangements are to be submitted for approval.

## Materials

705 The hull, superstructures, bulkheads, decks and deckhouses are to be of steel or other material which, by itself or due to insulation provided, has structural and fire integrity properties equivalent to steel. In cargo ships the use of other suitable material will be specially considered.

706 Pipes conveying oil or combustible liquids are to be of approved material having regard to the fire risk. Materials readily rendered ineffective by heat are not to be used for overboard scuppers, sanitary discharges and other outlets which are close to the water line and where the failure of the material in the event of fire would give rise to dangers of flooding.

## Section 8

## REQUIREMENTS FOR PASSENGER SHIPS CARRYING MORE THAN 36 PASSENGERS

## Main Vertical Fire Zones and Fire Divisions

801 The hull, superstructures and deckhouses are to be subdivided into main vertical fire zones, the mean length

of which on any one deck does not in general exceed 40 m, by "A" Class fire-resisting divisions as defined in the Safety Convention. Steps and recesses are to be kept to a minimum and are to be of "A" Class divisions.

So far as practicable, the bulkheads forming the boundaries of the main vertical fire zones above the bulkhead deck are to be in line with watertight subdivision bulkheads situated immediately below. Such bulkheads are to extend from deck to deck and to the shell or other boundaries.

## Openings in "A" Class Fire-resisting Divisions

802 Where "A" Class divisions are pierced for electric cables, pipes, trunks, ducts, girders, beams, etc., arrangements are to be made to ensure that the fire resistance is not impaired.

803 Dampers are to be fitted in ventilation trunks and ducts passing through main vertical fire zone bulkheads and are to have local control capable of operation from both sides of the bulkhead. The operating positions are to be readily accessible and marked in red lettering. Indicators are to be fitted to show whether the dampers are open or shut.

804 Except for tonnage openings and hatches to cargo, store and baggage spaces, all openings are to be provided with permanently attached means of closing which are to be at least as effective for resisting fires as the divisions in which they are fitted. Where "A" Class divisions are pierced by tonnage openings the means of closure are to be steel plates.

805 Doors and door frames in "A" Class divisions, with the means of securing them closed, are to provide resistance to fire and to the passage of smoke and flame equivalent to that of the bulkheads in which the doors are situated. Watertight doors need not be insulated.

Each door is to be capable of being opened from each side of the bulkhead by one person only. Fire doors in main vertical zone bulkheads other than watertight doors, are to be of the self-closing type with simple and easy means of release from the open position. These doors are to be of approved type, and the self-closing mechanism is to be capable of closing the door against an inclination of 3,5 degrees opposing closure.



**Bulkheads within Main Vertical Fire Zones**

806 In ships in which Safety Convention Method I or III fire protection arrangement is adopted, and in which an automatic sprinkler system is not to be fitted, the enclosure bulkheads within accommodation spaces, other than those required to be "A" Class fire-resisting divisions, are to be constructed of "B" Class fire-retarding divisions as defined in the Safety Convention. The arrangement of fire-retarding divisions will be specially considered in relation to the method of fire protection adopted.

Accommodation spaces are halls, dining rooms, lounges and similar permanently enclosed spaces, corridors, lavatories, cabins, offices, crew's quarters, barber shops, isolated pantries and lockers and similar spaces.

**Separation of Accommodation Spaces from Machinery, Cargo and Service Spaces**

807 The boundary bulkheads and decks separating accommodation spaces from machinery, cargo and service spaces are to be "A" Class fire-resisting divisions, the insulating value of which will be specially considered having regard to the nature of the adjacent spaces.

Machinery spaces include all spaces used for propelling, auxiliary or refrigerating machinery, boilers, pumps, workshops, generators, steering gear, ventilation and air conditioning machinery, oil filling stations and similar spaces and trunks to such spaces.

Service spaces are galleys, main pantries, stores (except isolated pantries and lockers), mail and specie rooms and similar spaces and trunks to such spaces.

Primary deck coverings within accommodation spaces, control stations, stairways and corridors are to be of approved material which will not readily ignite.

**Protection of Stairways in Accommodation and Service Spaces**

808 Stairways in accommodation and service spaces are to be of steel frame or other approved equivalent construction and are to be within enclosures formed of "A" Class divisions with positive means of closure at all openings from the lowest accommodation deck at least to a level which is directly accessible to the open deck, except that:—

- (1) a stairway connecting only two decks need not be enclosed, provided the integrity of the deck is maintained by proper bulkheads or doors at one level;
- (2) stairways may be fitted in the open in a public space, provided they lie wholly within such public space.

Stairway enclosures are to have direct communication with the corridors and are to be of sufficient area to prevent congestion having in view the number of persons likely to use them in an emergency, and are to contain as little accommodation, or other enclosed space in which a fire may originate, as practicable.

The insulation value of stairway enclosure bulkheads will be specially considered having regard to the nature of the adjacent spaces. The means for closure at openings in stairway enclosures are to be at least as effective for resisting fire as the bulkheads in which they are fitted. Doors other than watertight doors are to be of the self-closing type, as required for the main vertical fire zone bulkheads in accordance with 805.

The construction and protection of auxiliary stairways which do not form part of the general means of escape will be specially considered.

**Protection of Lift Trunks, Light and Air Trunks, Control Stations and Storerooms, etc.**

809 Passenger and service lift trunks, vertical trunks for light and air to passenger spaces, etc., are to be of "A" Class fire-resisting divisions. Doors are to be of steel or other equivalent material and when closed are to provide fire resistance at least as effective as the trunks in which they are fitted.

Lift trunks are to be so fitted as to prevent the passage of smoke and flame from one 'tween deck to another and are to be provided with means of closing so as to permit of draught and smoke control. Insulation need not be fitted to lift trunks which are within stairway enclosures.

Where a trunk for light and air communicates with more than one 'tween deck space and where smoke and flame are likely to be conducted from one 'tween deck to another, smoke shutters, suitably placed, are to be fitted so that each space can be isolated in case of fire.

Any other trunk (e.g. for electric cables) is to be so constructed as not to afford passage for fire from one 'tween deck or compartment to another.

810 Control stations are to be separated from the remainder of the ship by "A" Class bulkheads and decks.

Control stations are those spaces in which radio, main navigating or central fire-recording equipment or the emergency generator is located.

811 The boundary bulkheads of baggage rooms, mail rooms, store rooms, paint and lamp lockers, galleys and similar spaces are to be of "A" Class divisions. Spaces containing highly flammable stores are to be so situated as to minimize the danger to passengers or crew in the event of fire.



**Superstructures**

812 Superstructures of aluminium alloy will be specially considered in relation to the Safety Convention Method of fire protection adopted. Where the use of aluminium alloy is approved:—

- (1) Adequate provision is to be made to ensure that, in the event of fire, arrangements for stowage, launching and embarkation into lifeboats and rafts remain as effective as if the superstructures were constructed of steel; and
- (2) crowns and casings of boiler and machinery spaces are to be of steel adequately insulated, and any openings therein suitably arranged and protected to prevent spread of fire.

See F 324.

**Windows and Side scuttles**

813 All windows and side scuttles in bulkheads separating accommodation spaces and the weather are to be constructed with metal frames. The glass is to be retained by a metal glazing bead.

814 In spaces containing main propulsion machinery, or oil-fired boilers, or auxiliary internal combustion type of machinery to total power of 746 kW or over, the following provisions are to be made:—

- (1) skylights are to be capable of being closed from outside the space,
- (2) skylights containing glass panels are to be fitted with external shutters of steel or other equivalent material permanently attached,
- (3) any windows in casings of such spaces are to be of non-opening type and are to be fitted with external shutters of steel or other equivalent material permanently attached,
- (4) in the windows and skylights referred to above, wire-reinforced glass is to be used.

**Ventilation Systems**

815 The main inlets and outlets of all ventilation systems are to be capable of being closed from outside the space in the event of fire. In general, the ventilation fans are to be so disposed that the ducts reaching the various spaces remain within the same main vertical zone.

816 All power ventilation, except cargo and machinery space ventilation, is to be fitted with master controls so that all fans may be stopped from either of two separate positions situated as far apart as practicable. Two master controls are to be provided for the power ventilation serving machinery spaces, one of which can be operated from a position outside the machinery space.

817 Efficient insulation is to be provided for exhaust ducts from galley ranges where the ducts pass through accommodation spaces.

**Incombustible Materials**

818 In ships in which Safety Convention Method I fire protection arrangement is adopted, and in which an automatic sprinkler system is not to be fitted, all linings, grounds, ceilings and insulations are to be of incombustible materials except in cargo spaces, mail rooms, baggage rooms, or refrigerated compartments of service spaces.

819 In ships in which Safety Convention Method III fire protection arrangement is adopted, and in which an automatic sprinkler system is not to be fitted, the use of combustible materials of all kinds such as untreated wood, veneers, ceilings, curtains, carpets, etc., is to be reduced so far as practicable. In large public spaces, the grounds and supports to the linings and ceilings are to be of steel or equivalent material. All exposed surfaces in corridors or stairway enclosures and concealed or inaccessible spaces shall have low flame-spread characteristics.

**Automatic Sprinkler and Fire Alarm and Detection Systems**

820 In ships in which Safety Convention Method II fire protection arrangement is adopted, and in which "B" Class fire-retarding divisions are not to be fitted within accommodation spaces, an automatic sprinkler and fire alarm system of an approved type, and complying with the requirements of F 318 to F 324, is to be installed and so arranged as to protect all enclosed spaces appropriated to the use or service of passengers or crew, except spaces which afford no substantial fire risk. See M 507.

**Automatic Fire Alarm and Fire Detection Systems**

821 In ships in which Safety Convention Method III fire protection arrangement is adopted and in which an automatic sprinkler is not to be fitted, a fire-detecting system of an approved type is to be installed and so arranged as to detect the presence of fire in all enclosed spaces appropriated to the use or service of passengers or crew (except spaces which afford no substantial fire risk), and automatically to indicate at one or more points or stations where it could be most quickly observed by officers and crew, the presence or indication of fire and also its location.

**Miscellaneous Items**

822 In all parts of the ship, paints, varnishes and similar preparations having a nitro-cellulose or other highly flammable base are not to be used.



823 In all parts of the ship, pipes penetrating "A" or "B" Class fire divisions are to be of approved material having regard to the temperature such fire divisions are required to withstand.

824 In accommodation and service spaces, air spaces enclosed behind ceilings, panellings or linings are to be suitably subdivided by close-fitting draught stops not more than 14 m apart. In the vertical direction, such spaces, including those behind linings of stairways, trunks, etc., are to be closed at each deck. Small holes are to be arranged in ceilings and bulkheading, so that it will be possible, without impairing the efficiency of the fire protection, for the fire patrols to detect any smoke originating in concealed and inaccessible spaces. The concealed surfaces of all bulkheads, linings, panellings, stairways, wood grounds, etc., in accommodation spaces are to have low flame-spread characteristics.

### Section 9

#### **PASSENGER SHIPS CARRYING NOT MORE THAN 36 PASSENGERS**

901 Passenger ships to be classed for unrestricted service and carrying more than 12 passengers but not more than 36 passengers need comply only with the fire protection requirements in F 705, F 706, F 801 to F 805, F 807, F 809 (first sub-paragraph), F 810 to F 815, F 822 and F 823.

902 In addition, the following provisions shall apply:—

- (a) All stairways and means of escape in accommodation and service spaces shall be of steel or other suitable material.
- (b) Power ventilation of machinery spaces shall be capable of being stopped from an easily accessible position outside the machinery spaces.
- (c) Except where all enclosure bulkheads in accommodation spaces conform with the requirements in F 806, an automatic fire detection system conforming with F 402 is to be provided.

### Section 10

#### **REQUIREMENTS FOR CARGO SHIPS OF OVER 4000 TONS GROSS**

##### **Corridor Bulkheads in Accommodation**

1001 The corridor bulkheads in accommodation spaces are to be of steel or constructed of "B" class panels. The requirements of "B" class panels are specified in Chapter II Regulation 35 of the *Safety of Life at Sea Convention, 1960*.

##### **Protection of Interior Stairways, Lift Trunks, Galleys, Store-rooms, etc.**

1002 Interior stairways below the weather deck are to be of steel or other suitable material. Lift trunks within accommodation spaces shall be of steel or equivalent material. Bulkheads of galleys, paint stores, lamp rooms, boatswain's stores when adjacent to accommodation spaces and emergency generator rooms, if any, shall be of steel or equivalent material.

##### **Deck Coverings**

1003 Deck coverings within accommodation spaces on the decks forming the crown of machinery and cargo spaces shall be of a type which will not readily ignite.

##### **Ventilation Systems**

1004 Means shall be provided for stopping ventilating fans serving machinery and cargo spaces and for closing all doorways, ventilators, annular spaces around funnels and other openings to such spaces. These means shall be capable of being operated from outside such spaces in case of fire.

##### **Paints, etc.**

1005 In accommodation and machinery spaces, paints, varnishes and similar preparations having a nitro-cellulose or other highly flammable base are not to be used.

### Section 11

#### **REQUIREMENTS FOR CARGO SHIPS OF 500 TONS TO 4000 TONS GROSS**

1101 F 1004 is to be complied with.

NEW SECTION 12 HAS BEEN ADDED - SEE NOTICE No. 2.



## PART 3

## FIRE EXTINGUISHING ARRANGEMENTS IN TRAWLERS AND FISHING VESSELS

Section ~~12~~13

AMENDED SEE NOTICE No. 2

## WATER SERVICE AND FIRE PUMPS

## Fire Main and its Connections

1201 In all trawlers provision is to be made for pumping water for fire extinguishing service.

1202 The fire main is not to be of cast iron, and if made of iron or steel is to be galvanized. The wash deck line may be used as a fire main, provided it complies with the requirements of this Section.

1203 A relief valve is to be fitted in the engine room on the discharge line from the fire pumps to prevent any excessive pressure arising in the fire main.

The relief valve may be omitted where the maximum pump discharge pressure cannot greatly exceed the jet operating pressure.

1204 The sizes of the fire main and of its connections and fittings are to be sufficient to supply the fire hose required by 1205.

The hose nozzles used for extinguishing fires other than oil fires are to have a minimum bore of 12 mm.

1205 Hydrants are to be provided with shut-off cocks or valves. They are to be arranged so that any part of the trawler may be reached by a jet of water about 12 m in length through a single length of hose. Not less than two hoses are to be provided, one at each end of the trawler.

1206 All trawlers which use oil as fuel are to be provided with a fire hydrant in the machinery space, complete with hose having a nozzle suitable for spraying water on oil.

The hose is to be of sufficient length to permit an effective spray of water to reach any part of the engine or boiler rooms which contain oil fuel tanks or appliances.

## Fire Pumps

1207 In trawlers less than 150 tons gross, one power pump is to be available for fire extinguishing service.

1208 In trawlers of 150 tons gross and over, not less than two power pumps are to be provided, one of which is to be an independent pump.

1209 Fire pumps may be engine room general service pumps or ballast pumps, provided they are arranged to prevent oil being discharged accidentally into the fire extinguishing system.

1210 Each fire pump is to be capable of maintaining at the hose nozzle the 12 m jet of water required by 1205.

Section ~~14~~14

## FIRE EXTINGUISHING EQUIPMENT IN MACHINERY SPACES OF OIL BURNING STEAM TRAWLERS AND MOTOR TRAWLERS

## General Requirements

1301 The machinery spaces are to be provided with the fire hydrant and hose required by 1206.

1302 Provision is to be made for stopping from positions outside the machinery spaces, ventilating fans for these compartments, also other fans or blowers situated within the compartments, and for closing so far as practicable all openings to the machinery spaces.

The engine room skylights are to be capable of being shut from the deck, or from a safe position outside the machinery space.

Boiler rooms are to be provided with two separate means of access.

## Cross-references

1303 For other precautionary arrangements relating to oil leakage and outbreaks of fire, see E3 and E4, and SD 19 in the *Rules for Small Ships*.

Section ~~15~~15

## Oil Burning Steam Trawlers

1401 There is to be provided at each firing platform:—

- (a) A bin or bins containing not less than a total of 0,28 m<sup>3</sup> of sand, or other dry material suitable for extinguishing oil fires, with a scoop at each bin.
- (b) One portable fire extinguisher per burner, with a minimum of three extinguishers.



**1402** The number and position of the portable extinguishers are to be such that at least one extinguisher is situated within any compartment containing settling tanks or the whole or part of the oil fuel installation.

**1403** In boiler rooms and in any space in which oil fuel units or settling tanks are situated, a fire extinguishing apparatus is to be provided which can be controlled from outside these compartments, at positions which are easily accessible and which would not readily be cut off by an outbreak of fire in any of the above-mentioned compartments. If the engine and boiler rooms are not entirely separate and oil fuel can drain from one compartment to the other, these spaces shall be considered as one compartment.

The apparatus is to be capable of discharging rapidly, through a permanent piping system, a fire extinguishing medium which is to be either froth, CO<sub>2</sub> or steam.

#### Froth Apparatus

**1404** The froth apparatus is to be of the gravity type and capable of discharging froth to a depth of 150 mm over the largest area on which oil fuel is liable to spread in the event of a leakage of oil fuel.

Where the boilers are situated in an upper part of the machinery space, the above requirement applies also to the flat on which the boilers are situated.

**1405** Where the upper parts of the machinery spaces contain oil fuel tanks and appliances, additional fire protection is to be provided by fitting two portable extinguishers in the vicinity of these oil fuel tanks and appliances.

#### CO<sub>2</sub> Apparatus

**1406** The CO<sub>2</sub> fire extinguishing apparatus is to be capable of discharging gas in sufficient quantity to give a minimum volume of free CO<sub>2</sub> equal to 30 per cent of the gross volume of the largest space measured to the top of the boilers. The volume of the gas is to be taken as 0,56 m<sup>3</sup>/kg of liquefied CO<sub>2</sub>.

If the upper parts of the machinery spaces contain oil fuel tanks and appliances, it will be necessary to supply, in addition, the two portable extinguishers required by 1405.

**1407** If the CO<sub>2</sub> is supplied in sufficient quantity to give a minimum volume of free CO<sub>2</sub> equal to 30 per cent of the gross volume of the largest space measured to the top of the casing of the compartment, and the gas is discharged into the upper part of the space as well as into the lower part, the two portable extinguishers required by 1406 need not be provided.

**1408** The CO<sub>2</sub> fire extinguishing system is to be provided with an automatic audible alarm to operate when the

CO<sub>2</sub> is about to be injected into the machinery space or other working space. The arrangement of controls for the CO<sub>2</sub> apparatus is to be such that the apparatus may be operated only at the control station(s).

#### Steam Apparatus

**1409** Where steam is used as the fire extinguishing medium, it is to be led to pipes perforated for the emission of steam into the lower parts of the compartments. Where the boilers are situated in an upper part of the machinery space, the above requirement applies also to the flat on which the boilers are situated.

Steam for the apparatus is to be available in sufficient quantity from each boiler.

The perforated pipes are to be fitted not less than 150 mm above the tank top and bilges to avoid immersion in an accumulation of bilge water. If the pipes are of steel they are to be galvanized internally and externally. They are to be arranged to be self-draining. If the steam for the fire extinguishing system is obtained exclusively from water tube boiler(s), a 45 litre froth extinguisher is also to be provided.

Steam used for fire extinguishing purposes is to be saturated or de-superheated steam.

#### Steam Trawlers having Auxiliary Oil Engines

**1410** In oil burning steam trawlers where oil engines are installed as the main source of auxiliary power, two portable extinguishers additional to the above requirements are to be provided; otherwise, no additional equipment will be required.

In coal burning steam trawlers fitted with auxiliary oil engines, the fire extinguishing arrangements are to be submitted for consideration.

### Section 15/6

#### Motor Trawlers not fitted with Boilers

**1501** The extinguishers listed in Table F 15.1 are to be provided in the machinery space.

The number and position of the extinguishers are, however, to be such that at least one extinguisher is to be provided in each machinery space containing oil fuel tanks or appliances.

#### Motor Trawlers fitted with Oil Fired Boilers

**1502** In addition to the requirements of 1501, the requirements of F 1401 to F 1410, are to be complied with so far as they are applicable.



TABLE F 15.1

AGGREGATE SHAFT POWER OF MAIN AND AUXILIARY ENGINES in kW		NUMBER OF EXTINGUISHERS	
Exceeding	Not Exceeding	Portable	45 litres capacity or equivalent
—	373	2	—
373	746	2	1
746	—	3	2

In motor trawlers in which the oil fired boiler installation consists of a vertical boiler situated in the open engine room, the externally controlled fire extinguishing apparatus required by 1403 may be replaced by a froth extinguisher capable of providing not less than 150 mm of froth over the entire area of the oiltight tray or flat situated under the boiler. This tray is to be of adequate dimensions to ensure the collection of any oil escaping in the vicinity of the boiler.

## Section 15 17

### FIRE EXTINGUISHERS

1601 The extinguishers required for use in the machinery spaces of trawlers burning oil as fuel are to be of a type discharging froth, CO<sub>2</sub> or other approved medium suitable for extinguishing oil fires.

Portable extinguishers are to have a minimum capacity of 9 litres or equivalent, and a maximum capacity of 13,5 litres or equivalent.

The extinguisher capacities mentioned in these Rules refer to the quantity of fluid contained in the extinguishers.

1602 Portable extinguishers are to be fitted in readily accessible positions and a notice plate is to be provided stating that on no account are discharged extinguishers to be replaced in their holders until they have been replenished.

One extinguisher is to be fitted in the vicinity of the entrance door to the space in which it is intended to be used.

The positions of all extinguishers are to be approved by the Surveyors, due regard being paid to the location of the oil fuel appliances and the means of access to them.

1603 A spare charge is to be provided for each portable fire extinguisher which can be readily re-charged on board. If this cannot be done, duplicate extinguishers are to be provided.

1604 The makers of portable and fixed fire extinguishing appliances are to furnish a certificate stating the nature and quantity of the fire extinguishing medium. In the case of fixed froth or gas fire extinguishing systems, the makers are to state whether the quantity supplied is adequate to give the required depth of froth or gas concentration.

If considered necessary, the Committee may require the makers to produce evidence from a recognized independent testing authority regarding the suitability of their appliances.

### Acceptable Equivalents

- 1605 45 litres froth extinguisher—  
16 kg CO<sub>2</sub> extinguisher  
Portable froth extinguisher—  
4,5 kg CO<sub>2</sub> extinguisher

## Section 15 18

### Equivalent Arrangements

1701 Arrangements and appliances which differ from those mentioned in the foregoing requirements may be accepted, provided full details are submitted as early as practicable for the consideration of the Committee, and are found to be equivalent to the Society's requirements.



## Chapter G

# CONDITIONS FOR SURVEY OF MACHINERY DURING CONSTRUCTION

### Section 1

#### GENERAL REQUIREMENTS

101 The materials used in the construction of the machinery, boilers and pressure vessels are to comply with the requirements of Chapter Q. Materials, for which provision is not made in Chapter Q, may be accepted after compliance with such tests as may be imposed, under specifications to be approved before the materials are ordered and construction is commenced.

The machinery, boilers and pressure vessels are to be inspected throughout, the boilers and pressure vessels tested by hydraulic pressure, and the machinery tested under full power working conditions by the Society's Engineer Surveyors, who will furnish a report to the Committee. If found satisfactory, the Committee will thereupon grant a certificate, and insert in the *Register Book* the appropriate class notation, as set forth in Chapter B, indicating that the machinery, boilers and pressure vessels are certified to have been in good order and safe working condition on that date.

102 In cases of machinery which has been built under Special Survey, the distinguishing mark  $\nabla$  will be inserted before the appropriate class notation, as set forth in Chapter B.

103 In ships built under Special Survey, the following items of machinery are also to be constructed under Special Survey:—

The main and auxiliary engines and boilers, superheaters, economizers (including press boilers and similar

apparatus for floating whale-oil factories), steering engines, air receivers, air compressors, scavenge blowers and superchargers, oil fuel burning units, feed pumps, circulating and cooling water pumps, fire and bilge pumps, air pumps, ballast and oil fuel transfer pumps, water extraction pumps, lubricating oil pumps, fuel valve cooling pumps for oil engines, forced and induced draught fans, evaporators, distiller units, feed water heaters and pressure filters where the foregoing are intended for essential services, domestic boilers intended for working pressures exceeding 0,34 N/mm<sup>2</sup> (3,5 kgf/cm<sup>2</sup>) and having heating surfaces greater than 4,65 m<sup>2</sup> and athwartship thrust units including prime movers and control mechanism.

Generators and motors of 100 kW and over intended for essential services.

Motors intended for coupling to fans for the circulation of air in refrigerated cargo spaces.

Electric slip couplings.

All electric propelling machinery including switch-gear, control gear, cables, main and auxiliary generators, motor and excitors.

NOTE. Auxiliary boilers supply steam to auxiliary services essential to the operation of the ship at sea; but do not supply steam to the main propelling machinery.

Domestic boilers supply steam for purposes not connected in any way with the operation of the ship at sea.

104 In order to facilitate the inspection, plans in triplicate of the following items, together with the necessary particulars of the machinery, including the maximum power



and the revolutions per minute, are to be submitted for consideration before the work is commenced:—

Boilers, superheaters and economizers.

Air receivers.

Crank, thrust, intermediate and screw shafting and screwshaft oil gland.

Clutch and reversing gear with methods of control and flexible coupling.

Reduction gearing. (*See also* H 302.)

Propeller (including spare propeller if supplied). (*See also* H 402.)

General arrangement of shafting showing relative positions of the main engines, flywheel, flexible coupling, gearing, thrust block, line shafting and bearings, stern tube, "A" bracket and propeller, whichever is applicable.

Torsional vibration calculations for the shafting systems. *See* H 241 to H 243.

NOTES. Plans additional to the above should not be submitted unless the machinery is of a novel or special character affecting classification.

For Plans of Pumping and Piping required to be submitted, *see* E 101.

For Steam Turbines, *see* H 802.

For Gas Turbines, *see* H 902.

For Welded Structures for Oil Engines, *see* H 702.

For Welded Pressure Vessels, *see* J 104.

For Control Engineering Equipment, *see* L 102.

For Electrical Equipment and Electric Propelling Machinery, *see* M 102.

For Refrigerated Cargo Installations, *see* N 202.

**105** Where it is proposed to depart from the requirements of the Rules, the Committee will be prepared to give consideration to the circumstances of any special case.

**106** Any novelty in the construction of the machinery boilers or pressure vessels is to be reported to the Committee.

**107** The Surveyors are to examine and test the materials and workmanship from the commencement of the work until the final test of the machinery under full power working conditions; any defects, etc., are to be pointed out as early as possible.

**108** Where items of machinery are to be manufactured under batch or line production procedures, making normal survey methods difficult or inapplicable, the Committee will

be prepared on application to give consideration to the adoption of an alternative system of examination, involving periodical inspection of the works instead of survey of each individual item.

In order to obtain approval, the requirements of G 2 are to be complied with.

**109** The Surveyors may also, if requested, compare the work as it progresses with the requirements of the specification agreed upon by the parties concerned, and certify to the conditions thereof, so far as can be seen, being satisfactorily complied with.

**110** The machinery and boilers are to be securely fixed to the ship's structure to the satisfaction of the Surveyor. The bedplates, gearcases, thrust blocks and boiler fastenings are to be of robust construction.

**111** Refrigerating machinery using a toxic or flammable refrigerant, such as ammonia, is to be installed in an efficiently ventilated compartment isolated from the propelling machinery spaces and shaft tunnels, and living quarters.

Methyl chloride refrigerant is not to be used.

Machinery using non-toxic and non-flammable refrigerants will not be subject to restriction on location in general, but proposals to install relatively large plants in propelling machinery spaces will require special consideration.

#### Cross-references

**112** For conditions relating to the survey during construction of Electrical Equipment, Electrical Propelling Machinery and Refrigerating Machinery and Appliances, *see* M 1, M 17 and N 1 respectively.

## Section 2

### CERTIFICATION OF BATCH AND LINE PRODUCED MACHINERY

#### General

**201** The system for the certification of batch and line produced machinery is applicable to items of equipment produced in circumstances which would make the individual survey at all stages of manufacture impractical.

**202** The Committee will consider the proposed design for compliance with the Society's Rules, or other appropriate requirements, and the extent to which the manufacturing processes and control procedures ensure conformance of the product to the design.



203 Where the Committee consider that the requirements of 202 can be satisfactorily complied with, the manufacturers will, in general, be authorized to inspect and certify their products.

For products which require individual certification by the Society's Surveyors, delegation will be limited to certain preliminary aspects of manufacture. In the course of construction, the Surveyors are to examine and test such products and issue the final certificate.

204 The procedures and practices of manufacturers which have been granted approval, will be kept under continuous review.

#### Qualification for Approval

205 The manufacturer is required to demonstrate a clearly defined management structure.

The Quality Control Manager or Chief Inspector is to be acceptable to the Committee and should be responsible to management without being subject to the pressures of production output.

206 There is to be an efficient system for the control of drawings and technical data to ensure that all departments are working to the latest design information.

207 The manufacturer is to be responsible for ensuring that all supplies and services procured from suppliers and sub-contractors are of adequate quality and conform to the Society's requirements. The Committee reserves the right to inspect, at source, any supplies manufactured by sub-contractors.

208 The arrangements for the handling, transportation and storage of material and components should ensure that such items are not adversely affected and, at all times, bear sufficient indication of identity and status.

209 The manufacturer should follow a policy for recruitment and training which provides an adequate labour force with such skills as are required for each type of work operation. There should be adequate supervision to ensure that standards of workmanship are maintained.

210 The quality control/inspection department should be staffed and equipped adequately to implement the quality control programme.

211 The manufacturer is to provide and maintain adequate and effective measuring and testing devices which are to be calibrated against certified measurement standards at established periods to assure continued accuracy.

212 The manufacturer is to operate a quality control programme appropriate to the product design and manufacturing techniques, which will ensure adequate quality standards at all stages of production, including sub-contracted work. The programme is to provide for the ready detection of discrepancies and for timely and effective corrective action.

213 The manufacturer is to maintain adequate records of supplies and services indicating the materials, deliveries, acceptances and rejections, so that variations in the quality of supplies and services can be readily observed by the Surveyors.

214 An effective system is to be maintained for the control of non-conforming material, including procedures for its identification, segregation and disposal. There should be adequate procedures for the repair, rework or disposal of non-conforming materials and components.

215 Records of inspection and test are considered to be one of the principal forms of objective evidence of quality, and these are to be complete and reliable. These records are to be available for review by the Society's Surveyors, and copies of individual records are to be furnished to the Surveyors on request.

216 Statistical quality control methods may be used, where suitable, to maintain control of quality. Wherever possible, these methods should be based on established procedures.

#### Survey of Works

217 The Society's Surveyors will assess the manufacturing processes and control procedures of manufacturers applying for approval. The procedures employed are to be sufficiently documented to allow appraisal by the Surveyors.

218 Gauging, measuring and testing devices are to be made available to the Surveyors and, where appropriate, personnel for the operation of such devices.

219 The Surveyors will not specify in detail the procedures to be employed, but will consider the arrangements proposed by the manufacturer in relation to process and product. However, they may advise a manufacturer how the quality control programme might be improved.

In the event of procedures being considered inadequate, the Surveyors will advise the manufacturer how such procedures may be revised to be acceptable to the Society.



220 Approval by another organization will not be accepted as sufficient evidence that a manufacturer's arrangements comply with the Society's requirements.

#### Approval of Works

221 A certificate will be issued to each Approved Works indicating the products for which approval has been granted. The certificate will be valid for one year and renewal will be subject to satisfactory re-survey.

222 Manufacturers may obtain extension of approval in respect of further products of their own manufacture, at the discretion of the Committee without additional survey of their works.

223 The Society will publish a list of manufacturers whose works have been approved and are under continuous survey.

#### Product Certification

224 Nominated personnel of the manufacturer will be authorized to certify that the product conforms to its design specification and to the requirements of Lloyd's Register of Shipping.

#### Continuous Review Arrangements

225 The quality control arrangements of an Approved Works will be kept under continuous review and the whole of the manufacturer's activities in this respect are to be open to periodical and systematic surveys by the Surveyors at all reasonable times. The Surveyors will indicate immediately to the Quality Control Manager, or Chief Inspector, any matter with which they are not satisfied.

226 The Society's Surveyors will visit the works at intervals determined by the nature of the product, rate of production and standard of quality control arrangements.

227 In the event of noteworthy departures from the drawing or specification being accepted, a standard "Concession" form is to be completed and signed by both the Design Manager and the Quality Control Manager, or their authorized deputies. In all cases where strength or functioning may be affected, the form is to be submitted to the Surveyors for approval and endorsement.

228 Maintenance of approval will be subject to the continuance of those details of supplies, organization, procedures and methods which formed the basis for granting approval. Where changes are proposed, the attending Surveyors are to be advised in order that consideration can be given to such changes.

229 When appropriate, the Surveyors may apply intensive supervision, possibly including a degree of direct inspection.

#### Suspension or Withdrawal of Approval

230 When the Surveyors are satisfied that a fault or deficiency in the manufacturer's arrangements, previously pointed out, has not been rectified in a reasonable time, the manufacturer will be notified, in writing, of the Committee's intention to suspend approval.

231 When approval has been suspended and the manufacturer has proved unable or unwilling to take corrective action, approval will be withdrawn.



## Chapter H

# MAIN AND AUXILIARY ENGINES AND ASSOCIATED MACHINERY COMPONENTS

### Scope

The requirements of this Chapter are applicable to main and auxiliary engines including oil engines, steam and gas turbines, gearing and other associated machinery components.

The main and auxiliary engines are to be made in accordance with the requirements contained in the following Sections, where applicable:—

#### Section 1 General Requirements.

- „ 2 Shafting for Oil Engine, Turbine and Electric Propulsion Installations.
- „ 3 Reduction Gearing for Propelling and Auxiliary Engines.
- „ 4 Propellers.
- „ 5 Strengthening for Navigation in Ice.
- „ 6 General Requirements for Oil Engines and Starting Air Compressors.
- „ 7 Welded Structures for Oil Engines.
- „ 8 General Requirements for Steam Turbines.
- „ 9 General Requirements for Gas Turbines.

NOTE. For steam reciprocating engines, with or without exhaust steam turbines, the appropriate requirements of the *Society's Rules for Steel Ships, 1969* are to be complied with.

### Section 1

#### GENERAL REQUIREMENTS

##### Materials

101 Materials for crankshafts, turbine rotors, pinions, gear wheels, shafts including line shafting, propellers and other important machinery parts are to be made and tested under the supervision of the Surveyors in accordance with the appropriate requirements of Chapter Q or, in special cases, with an approved specification.

102 Where it is proposed to use non-ferrous metal for shafting, details of the specification and method of manufacture are to be submitted for consideration.

##### Inspection

103 The surfaces of shafting and other important machinery parts are to be examined when finish machined and, if required by the Surveyors, also in the rough machined condition.

##### Definitions

104 The watt, W, is the SI unit for power and is used with multiples where appropriate. Where shaft horse power, shp, is shown in brackets it is to be taken as metric horse power and is equivalent to 0,735 kW and 75 kgf m per second.



**Operating Conditions and Power Ratings**

**105** In the Sections in this Chapter where the dimensions of any particular component are determined on shaft power, kW (shp), and revolutions per minute, denoted by H and R respectively, the appropriate values to be used in the relevant formulæ are to be derived from the following:—

- (a) For main propelling machinery, the maximum propulsion shaft power and corresponding revolutions per minute for which the machinery is to be classed.
- (b) For auxiliary machinery, the maximum continuous shaft power and corresponding revolutions per minute which will be used in service.

**106** The rating of main and essential auxiliary machinery intended for installation in sea-going ships to be classed for unrestricted (geographical) service should be based on a sea temperature not less than 30°C and an engine room ambient temperature not less than 45°C. In the case of ships to be classed for restricted service, the rating should be suitable for the temperature conditions associated with the geographical limits of the restricted service. See B 118 to B 122.

**107** Auxiliary engines coupled to electrical generators are to be capable under service conditions of developing continuously the power to drive the generators at full rated output (kW) and in the case of oil engines of developing for a short period (15 minutes) an overload power of not less than 10 per cent (see M 106, M 403 and M 404).

Enginebuilders should satisfy the Surveyors by tests on individual engines that the above requirements, as applicable, can be complied with, due account being taken of the difference between the temperatures under test conditions and those referred to in 106. Alternatively, where it is not practicable to test the engine/generator set as a unit, type tests, e.g. against a brake, representing a particular size and range of engines may be accepted. With oil engines and gas turbines, any fuel stop fitted should be set so as to permit the short period overload power of not less than 10 per cent above full rated output (kW) being developed.

**Alignment Gauges and Wear-down Gauges**

**108** All main and auxiliary oil engines exceeding 220 kW (300 shp) are to be provided with an alignment gauge which may be either a bridge wear-down gauge, or a micrometer clock gauge for use between the crankwebs. Only one micrometer clock gauge need be supplied for each ship provided the gauge is suitable for use on all engines.

Main and auxiliary turbines are to be provided with bridge wear-down gauges for testing the alignment of the rotors.

Reduction gears with sleeve bearings, for main and auxiliary turbines and oil engines, are to be provided with bridge wear-down gauges for testing the internal alignment of the various elements in the gear cases. In certain gears, e.g. gears of the locked train type, the direction of loading on the bearings of a gear element may be such that an accurate indication of its alignment under operating conditions cannot be obtained using the bridge type wear-down gauge. In these instances, suitable alternatives such as crown thickness micrometers are to be provided.

The Surveyors are to witness the initial readings of the wear-down gauges.

In the case of reduction gearing for main turbines and oil engines, also for auxiliary turbines and oil engines exceeding 220 kW (300 shp), trammels or other approved means are to be provided by the gear manufacturer to enable the Surveyors to verify that no distortion of the gearcase has taken place, when chocked and secured to its seating on board ship.

**Cross-references**

**109** For means of escape from machinery spaces and communication between bridge and engine room, see D 2113 and D 2114.

**Section 2****SHAFTING FOR OIL ENGINE, TURBINE AND  
ELECTRIC PROPULSION INSTALLATIONS****General**

The requirements of this Section relate, in particular, to formulæ for determining the diameters of shafting for main propulsion and auxiliary machinery installations but requirements for torsional vibrations, couplings, coupling bolts, keys, keyways, sternbushes and other associated components are also included.

The Section is divided into three parts as follows:—

- Part 1 Crankshafts for Oil Engines. NEW PARA.  
Paragraph Nos. 201 to 208.
- Part 2 Gear and Line Shafting and Associated Components for Oil Engine, Turbine and Electric Propulsion Installations. SEE NOTICE No. 1.  
Paragraph Nos. 221 to 236.
- Part 3 Torsional Vibrations.  
Paragraph Nos. 241 to 243.



## PART 1

## CRANKSHAFTS FOR OIL ENGINES

## Material

201 Material specifications for steel crankshafts, forging procedures and heat treatment details are to be submitted.

202 Where it is proposed to make crankshafts of cast iron, the material specification and the dimensions of the shaft are to be submitted for special consideration.

The material specification should state the type of cast iron, the heat treatment, and mechanical properties, including the specified minimum tensile strength appropriate to the section of the crankshaft casting.

Any suitable type of high duty cast iron may be used, provided the minimum specified tensile strength is between 310 and 750 N/mm<sup>2</sup> (32 and 76 kgf/mm<sup>2</sup>). Crankshafts are to be cast at a foundry approved for the production of cast iron crankshafts and are to be in accordance with Q 8.

## Crankshafts

203 For steel crankshafts of solid forged, cast, semi-built and built construction, also for cast iron crankshafts, the power rating of the engine is not to exceed that given by the following formula:—

$$\frac{H_o}{R_o} = \frac{nE}{764,6 CK_1} \left[ \frac{d^3 Z (T+157)}{700\,000} - \frac{AK_2 P (l-l_p) D^2}{100\,000} \right]$$

$$\left( \frac{H_o}{R_o} = \frac{nE}{5730,5 CK_1} \left[ \frac{d^3 Z (T+16)}{7000} - \frac{AK_2 P (l-l_p) D^2}{100\,000} \right] \right)$$

NOTE. The power rating  $\frac{H_o}{R_o}$  is not to be less than the power rating based on H and R as defined in H 105.

where  $H_o$  = maximum designed shaft power, in kW (shp),

$R_o$  = revolutions per minute of the crankshaft at maximum designed shaft power,

$n$  = number of cylinders for 2SCSA engines,  
= half the number of cylinders for 4SCSA engines,

$E$  = mechanical efficiency of the engine expressed as a decimal,

$A$  and  $C$  = coefficients from Tables H 2.1, H 2.2, H 2.3 or H 2.4 for appropriate cycle and firing order with equal intervals between firing (cylinders numbered from the free end of the engine),

$K_1 = 0,8 + \frac{u}{3d_p} + 0,243 \sqrt{\frac{d_p}{r}}$  for solid forged steel or cast iron crankshafts and the combined pins and webs of semi-built forged or cast steel crankshafts,

$K_1 = 1,8$  for shrunk sections of forged or cast steel semi-built and built crankshafts,

$d_p$  = diameter of crankpin, in mm,

$r$  = fillet radius at junction of crankweb with crank pin, in mm. (The fillet radius at junction of journal and crankweb is not to be less than  $r$ ),

$u = d_p + d_j - S$

$d_j$  = diameter of crank journal, in mm,

$S$  = length of stroke, in mm,

$d$  = minimum diameter of crankshaft pin or journal, whichever is less, or equivalent diameter for hollow shafting, in mm,

$Z = 1,0$  except as follows:—

= 1,15 for die-forged crankshafts and continuous grain-flow crankshafts where these methods of manufacture or processing have been specially approved,

= 1,25 for crankshafts surface-hardened by nitriding where full particulars of the method and process have been approved. (NOTE. Special consideration will be given to other surface-hardening treatments which include the fillet radii, in allocating an appropriate  $Z$  value. If it can be proved that any surface-hardening process will further improve the fatigue characteristics of die-forged or continuous grain flow crankshafts, consideration will be given to the use of a combined  $Z$  value),

$$= \frac{T + 260 - 0,059 d}{1,23 (T + 157)}$$

$$\left( = \frac{T + 26,5 - 0,006 d}{1,23 (T + 16)} \right)$$

for cast iron crankshafts.

$T$  = specified minimum tensile strength of crankshaft material, in N/mm<sup>2</sup> (kgf/mm<sup>2</sup>),

$K_2 = 7,0$  for shrunk sections of forged or cast steel semi-built and built crankshafts,



$K_2 = QFG \sqrt{\frac{d_p}{r}}$  for solid forged steel or cast iron crankshafts and the combined pins and webs of semi-built forged or cast steel crankshafts,

$Q$  = coefficient from Fig. H 2.1,

(NOTE.  $Q$  is to be taken as 1.0 for all negative values of  $\frac{u}{d_p}$  greater than 0.6),

$m$  = depth of recess of fillet into crankweb, in mm,

$F$  = coefficient from Fig. H 2.2,

$b$  = breadth of web, in mm,

$G$  = coefficient from Fig. H 2.3 or Fig. H 2.4,

$t$  = axial thickness of web, in mm,

$P$  = maximum combustion pressure, in  $N/mm^2$  ( $kgf/cm^2$ ), at maximum designed shaft power,

$l$  = span of bearings adjacent to a crank measured from inner edge to inner edge, in mm,

$l_p$  = length of crankpin, in mm,

$D$  = diameter of cylinder, in mm.

Engines having unequal firing intervals or not covered by values of  $A$  and  $C$  given in Tables H 2.1, H 2.2, H 2.3 or H 2.4 and Vee engines having different firing orders on each bank will receive special consideration.

For Vee engines having minimum firing intervals between two cylinders on one pin different from those given in Tables H 2.3 or H 2.4, the values of  $A$  and  $C$  may be obtained by interpolation.

**204** In designs of crankshafts to which the engine power rating formula in 203 is not directly applicable, detailed design calculations are to be submitted for special consideration.

**205** Special consideration will be given to cast iron crankshafts which have been designed and developed for optimum fatigue strength with cranks of the most favourable shape, and some allowance made for the superior strength thereby obtained. Particulars of any relevant tests or experience should be submitted.

### Crankwebs of Built and Semi-built steel Shafts

**206** Where the crankwebs are shrunk on crankpins or journals, the dimensions and yield stress of the material of the crankwebs are not to be less than given by the following formulæ for the shrinkage allowance proposed:—

$$t = \frac{d_r^3 (d_o + 2h)^2}{6250 S_1 k d_o h (d_o + h)} \text{ mm}$$

$$f_y = 92180 S_2 \frac{k}{d_o} \left[ 1 + \left( \frac{d_o}{d_o + 2h} \right)^2 \right] \text{ N/mm}^2$$

$$(f_y = 9400 S_2 \frac{k}{d_o} \left[ 1 + \left( \frac{d_o}{d_o + 2h} \right)^2 \right] \text{ kgf/mm}^2)$$

where  $t$  = axial thickness of web which is not to be less than  $0.525 d_r$ , in mm,

$d_r$  = minimum diameter of crankshaft determined by 203 using  $K_1 = 1.8$ ,  $K_2 = 7.0$ ,  $Z = 1.0$  and  $T = 430 \text{ N/mm}^2$  ( $44 \text{ kgf/mm}^2$ ) for the proposed power rating, in mm,

$d_o$  = diameter of hole in crankweb, in mm,

$h$  = radial thickness of metal around hole in crankweb, in mm,

$S_1$  = minimum shrinkage allowance at pins or journals, in mm,

$S_2$  = maximum shrinkage allowance at pins or journals, in mm,

$k = 1$  for solid pins or journals or as determined from Fig. H 2.5 for pins or journals with central holes,

$d_l$  = diameter of holes in pins or journals, in mm,

$f_y$  = specified minimum yield stress of the material of the crankweb, in  $N/mm^2$  ( $kgf/mm^2$ ).

**207** Reference marks are to be provided on the outer junction of the crankwebs with the crankpins and journals.

### Fillets and Oil Holes

**208** Fillets at the junctions of crankwebs with crankpins or journals, where these are formed as solid forgings or castings, are to have a smooth finish.

Oil holes at the surfaces of crankpins and journals are to be rounded to an even contour with a smooth finish.



**TABLE H 2.1**  
**CRANKSHAFT COEFFICIENTS A AND C FOR 2SCSA ENGINES**

NO. OF CYLS.	FIRING ORDER FROM FREE END OF ENGINE (EQUAL INTERVALS)	FORWARD FIRING		REVERSE FIRING	
		A	C	A	C
2	1-2	0,41	2,5	0,41	2,5
3	1-2-3	0,38	3,9	0,38	3,9
4	1-2-3-4	0,36	4,5	0,36	4,5
	1-2-4-3	0,36	4,5	0,36	4,5
	1-3-2-4	0,36	4,6	0,36	4,6
5	1-2-4-5-3	0,34	5,4	0,34	5,4
	1-2-5-3-4	0,36	4,9	0,36	4,9
	1-3-5-2-4	0,35	5,0	0,35	5,1
	1-4-3-2-5	0,35	5,0	0,35	5,0
6	1-3-5-2-4-6	0,36	5,0	0,37	4,3
	1-4-2-6-3-5	0,38	3,9	0,38	3,9
	1-4-3-5-2-6	0,38	3,9	0,38	3,9
	1-4-5-2-3-6	0,36	5,0	0,37	4,3
	1-5-3-4-2-6	0,38	3,9	0,38	3,9
7	1-4-6-2-5-3-7	0,38	3,7	0,35	5,4
	1-4-7-2-3-5-6	0,35	5,3	0,35	5,4
	1-5-2-6-4-3-7	0,37	4,4	0,37	4,4
	1-5-3-6-2-4-7	0,38	3,6	0,35	5,4
	1-5-4-6-2-3-7	0,37	4,3	0,35	5,0
	1-6-3-4-5-2-7	0,37	4,4	0,37	4,4
	1-6-3-5-4-2-7	0,37	4,4	0,37	4,4
8	1-5-4-7-2-6-3-8	0,34	5,8	0,34	5,8
	1-5-6-2-7-3-4-8	0,35	5,2	0,35	5,2
	1-5-8-2-4-7-3-6	0,35	5,5	0,35	5,5
	1-6-3-7-2-5-4-8	0,34	5,8	0,34	5,8
	1-6-3-8-2-5-4-7	0,34	5,8	0,34	5,8
	1-6-4-2-7-3-5-8	0,35	5,2	0,35	5,2
	1-6-4-2-8-3-5-7	0,35	5,2	0,35	5,2
	1-6-4-7-2-5-3-8	0,34	5,8	0,34	5,8
	1-6-5-2-7-4-3-8	0,35	5,2	0,35	5,2
	1-6-5-2-8-3-4-7	0,35	5,2	0,35	5,2
	1-7-2-5-4-6-3-8	0,32	6,7	0,32	6,7
	1-7-3-4-6-5-2-8	0,32	6,7	0,32	6,7
	1-7-3-5-4-6-2-8	0,32	6,7	0,32	6,7
	1-7-4-3-6-5-2-8	0,32	6,7	0,32	6,7
9	1-4-9-2-5-7-3-6-8	0,33	6,6	0,33	6,6
	1-4-9-7-2-3-6-8-5	0,35	6,1	0,35	6,1
	1-5-7-3-8-2-6-4-9	0,35	5,1	0,35	5,1
	1-5-9-2-4-7-3-6-8	0,33	6,6	0,33	6,6
	1-6-7-2-5-8-3-4-9	0,33	6,6	0,33	6,6
	1-6-7-3-4-9-2-5-8	0,33	6,6	0,33	6,6
	1-6-7-3-5-8-2-4-9	0,33	6,6	0,33	6,6
	1-6-8-2-5-7-3-4-9	0,33	6,6	0,33	6,6
	1-7-5-3-9-2-6-4-8	0,35	5,1	0,35	5,1
	1-8-3-6-5-4-7-2-9	0,32	6,8	0,32	6,8
10	1-5-9-3-4-8-7-2-6-10	0,31	7,6	0,31	7,6
	1-6-4-9-3-8-2-7-5-10	0,33	6,3	0,33	6,2
	1-6-5-9-2-8-3-7-4-10	0,33	6,3	0,33	6,2
	1-6-9-2-5-10-3-4-7-8	0,31	7,6	0,32	7,4
	1-6-9-2-5-10-4-3-8-7	0,31	7,6	0,32	7,1
	1-6-10-2-4-9-5-3-7-8	0,31	7,6	0,32	7,4
	1-7-3-9-5-6-2-8-4-10	0,33	6,3	0,33	6,3
	1-7-6-3-9-2-8-5-4-10	0,34	5,9	0,32	6,9
	1-7-8-3-4-10-2-6-5-9	0,32	6,7	0,33	6,3
	1-7-9-2-4-10-3-5-6-8	0,32	6,7	0,32	7,4
	1-8-4-7-2-10-3-6-5-9	0,33	6,2	0,33	6,1
	1-8-5-4-9-2-7-6-3-10	0,34	5,9	0,32	6,9
	1-8-5-6-3-10-2-7-4-9	0,33	6,1	0,33	6,2
	1-8-5-7-2-10-3-6-4-9	0,33	6,2	0,33	6,1
	1-9-3-7-5-6-4-8-2-10	0,31	7,6	0,31	7,6
	1-9-4-5-8-3-6-7-2-10	0,31	7,6	0,31	7,6
11	1-9-5-7-3-11-2-8-6-4-10	0,34	6,1	0,34	6,0
	1-9-6-4-10-2-8-5-7-3-11	0,32	7,2	0,31	7,9
	1-10-3-8-6-5-7-4-9-2-11	0,30	8,3	0,30	8,3
12	1-4-8-12-3-5-7-10-2-6-9-11	0,34	5,8	0,32	7,0
	1-5-11-9-2-4-12-7-3-6-10-8	0,32	7,0	0,32	7,1
	1-5-12-7-2-6-10-8-3-4-11-9	0,32	7,0	0,31	8,3
	1-6-8-10-3-5-7-12-2-4-9-11	0,34	5,8	0,32	7,0
	1-6-11-7-3-5-10-9-2-4-12-8	0,32	7,0	0,33	6,5
	1-8-6-10-2-9-4-11-3-5-7-12	0,31	8,3	0,31	8,3
	1-8-6-10-2-9-4-11-3-7-5-12	0,31	8,3	0,31	8,3
	1-9-5-10-3-8-4-12-2-7-6-11	0,31	8,2	0,31	8,3
	1-10-5-7-9-2-12-3-8-6-4-11	0,33	6,8	0,33	6,8

TABLE H 2.2

## CRANKSHAFT COEFFICIENTS A AND C FOR 4SCSA ENGINES

NO. OF CYLS.	FIRING ORDER FROM FREE END OF ENGINE (EQUAL INTERVALS)	FORWARD FIRING		REVERSE FIRING	
		A	C	A	C
2	1-2	0,43	2,5	0,43	2,5
3	1-2-3	0,41	3,2	0,41	3,2
4	1-2-3-4	0,42	2,8	0,42	2,8
	1-2-4-3	0,42	2,8	0,42	2,8
5	1-2-4-5-3	0,38	4,5	0,38	4,6
	1-4-3-2-5	0,38	4,7	0,38	4,6
6	1-2-3-6-5-4	0,41	3,4	0,41	3,4
	1-2-4-6-3-5	0,40	3,9	0,40	3,9
	1-2-4-6-5-3	0,41	3,4	0,41	3,4
	1-2-5-6-4-3	0,41	3,4	0,41	3,4
	1-4-2-6-3-5	0,40	3,9	0,40	3,9
7	1-2-4-6-7-5-3	0,37	5,0	0,37	5,1
8	1-2-3-5-8-7-6-4	0,38	4,9	0,38	4,9
	1-2-4-6-8-7-5-3	0,38	4,9	0,38	4,9
	1-2-5-6-8-7-4-3	0,38	4,9	0,38	4,9
	1-3-2-4-8-6-7-5	0,39	4,4	0,39	4,4
	1-3-2-5-8-6-7-4	0,39	4,4	0,39	4,4
	1-3-5-2-8-6-4-7	0,37	5,2	0,37	5,2
	1-3-7-4-8-6-2-5	0,38	4,9	0,38	4,8
	1-4-6-2-8-5-3-7	0,37	5,2	0,37	5,2
	1-4-7-3-8-5-2-6	0,37	5,2	0,37	5,2
	1-5-2-6-4-8-3-7	0,39	4,5	0,39	4,5
	1-5-3-2-8-4-6-7	0,37	5,2	0,37	5,2
	1-5-7-3-8-4-2-6	0,37	5,2	0,37	5,2
	1-6-4-2-8-3-5-7	0,37	5,2	0,37	5,2
9	1-2-4-6-8-9-7-5-3	0,37	5,5	0,37	5,5
	1-4-2-3-7-8-6-9-5	0,37	4,9	0,37	5,4
	1-4-7-2-6-9-3-5-8	0,37	5,3	0,37	5,3
	1-5-9-3-6-8-2-4-7	0,37	5,3	0,37	5,3
	1-5-9-3-7-8-2-4-6	0,37	5,3	0,37	5,3
10	1-4-3-2-5-10-7-8-9-6	0,37	5,1	0,37	5,2
	1-4-8-2-5-10-7-3-9-6	0,37	5,4	0,37	5,4
	1-6-2-8-4-10-5-9-3-7	0,37	5,4	0,36	5,4
	1-6-9-3-4-10-5-2-8-7	0,36	5,8	0,35	5,8
12	1-3-8-11-9-7-12-10-5-2-4-6	0,35	6,3	0,35	6,3
	1-9-2-7-4-8-6-10-5-12-3-11	0,37	5,7	0,37	5,7



TABLE H 2.3

## CRANKSHAFT COEFFICIENTS A AND C FOR 2SCSA VEE ENGINES

NO. OF CYLS.	FIRING ORDER PER BANK FROM FREE END OF ENGINE (EQUAL INTERVALS)	FIRING INTERVAL BETWEEN TWO CYLINDERS ON ONE PIN									
		36°		45°		50°		63,5°		90°	
		A	C	A	C	A	C	A	C	A	C
4	1-2	0,64	3,6	0,55	3,7	0,54	3,7	0,53	3,6	0,53	3,8
6	1-2-3	0,61	4,9	0,52	4,9	0,52	5,0	0,50	5,3	0,50	5,7
	1-3-2	0,61	5,0	0,52	5,3	0,51	5,4	0,50	5,4	0,50	5,2
8	1-2-4-3	0,59	6,5	0,49	6,5	0,49	6,6	0,47	6,8	0,43	9,2
	1-3-2-4	0,59	6,0	0,51	5,6	0,50	5,6	0,47	6,8	0,43	9,2
	1-3-4-2	0,59	6,5	0,49	6,5	0,49	6,6	0,47	6,8	0,43	9,2
	1-4-2-3	0,59	5,9	0,51	5,6	0,50	5,6	0,47	6,8	0,43	9,2
10	1-4-3-2-5	0,59	6,1	0,49	6,7	0,47	7,4	0,43	9,4	0,45	8,1
	1-5-2-3-4	0,59	6,2	0,49	6,7	0,47	7,4	0,43	9,4	0,45	8,1
12	1-3-5-2-4-6	0,57	7,4	0,45	9,0	0,43	9,8	0,40	10,6	0,46	7,6
	1-5-3-4-2-6	0,57	7,4	0,45	9,0	0,43	9,8	0,40	10,6	0,46	7,6
	1-6-2-4-3-5	0,57	7,4	0,45	9,0	0,43	9,8	0,40	10,6	0,46	7,6
	1-6-4-2-5-3	0,57	7,4	0,45	9,0	0,43	9,8	0,40	10,6	0,46	7,6
14	1-6-3-4-5-2-7	0,54	9,0	0,43	10,3	0,41	10,7	0,41	10,1	0,41	10,3
	1-7-2-5-4-3-6	0,54	9,0	0,42	10,6	0,40	10,7	0,41	10,4	0,42	9,6
16	1-6-4-7-2-5-3-8	0,56	7,9	0,42	11,2	0,41	11,2	0,42	10,2	0,39	11,4
	1-8-3-5-2-7-4-6	0,56	7,9	0,42	11,2	0,41	11,2	0,42	10,2	0,39	11,4
18	1-6-8-2-5-7-3-4-9	0,51	11,4	0,41	12,0	0,41	11,6	0,41	10,8	0,40	11,9
	1-9-4-3-7-5-2-8-6	0,51	11,4	0,40	12,4	0,40	11,8	0,40	11,5	0,40	11,9
20	1-8-5-7-2-10-3-6-4-9	0,50	12,6	0,41	12,5	0,40	12,4	0,40	12,1	0,40	12,3
	1-9-4-6-3-10-2-7-5-8	0,50	12,6	0,41	12,7	0,40	12,4	0,39	12,4	0,40	12,3

## CRANKSHAFT COEFFICIENTS

NO. OF CYLS.	FIRING ORDER PER BANK FROM FREE END OF ENGINE (EQUAL INTERVALS)	MINIMUM FIRING INTERVAL											
		40°		45°		50°		60°		80°		90°	
		A	C	A	C	A	C	A	C	A	C	A	C
4		0,67	3,4	0,63	3,5	0,61	3,5	0,59	3,5	0,56	3,7	0,54	3,8
6	ALL	0,65	4,7	0,60	4,8	0,58	4,8	0,56	5,0	0,54	4,6	0,54	4,2
8	ALL	0,67	3,8	0,63	3,9	0,61	3,8	0,58	3,8	0,55	3,9	0,54	4,5
10	1-2-4-5-3	0,60	6,7	0,57	6,5	0,56	6,2	0,54	5,7	0,53	4,9	0,52	5,1
	1-3-5-4-2	0,60	6,8	0,57	6,4	0,55	6,1	0,54	5,6	0,53	4,9	0,52	5,1
12	1-2-4-6-3-5	0,63	5,9	0,58	5,9	0,56	5,9	0,54	5,9	0,51	5,8	0,50	5,7
	1-2-4-6-5-3	0,63	5,4	0,59	5,5	0,57	5,6	0,54	5,7	0,51	5,9	0,52	5,7
	1-2-5-6-4-3	0,63	5,4	0,59	5,5	0,57	5,6	0,54	5,8	0,50	6,1	0,50	6,2
	1-3-4-6-5-2	0,63	5,4	0,59	5,5	0,57	5,6	0,54	5,7	0,51	5,7	0,52	5,7
	1-3-5-6-4-2	0,63	5,4	0,59	5,5	0,57	5,6	0,54	5,9	0,51	5,9	0,50	6,1
	1-4-2-6-3-5	0,64	5,9	0,58	5,9	0,56	5,9	0,54	5,9	0,51	5,8	0,50	5,7
	1-5-3-6-2-4	0,64	5,9	0,58	5,9	0,56	5,9	0,54	5,9	0,53	5,4	0,50	5,9
	1-5-3-6-4-2	0,63	5,9	0,58	5,9	0,56	5,9	0,54	5,9	0,51	5,7	0,52	5,7
14	1-2-4-6-7-5-3	0,61	6,6	0,57	6,5	0,56	6,2	0,52	7,0	0,47	8,3	0,44	9,2
	1-3-5-7-6-4-2	0,60	6,6	0,57	6,6	0,56	6,3	0,52	6,5	0,47	8,5	0,45	9,1
16	1-2-4-6-8-7-5-3	0,59	7,6	0,55	7,6	0,54	7,5	0,50	7,6	0,45	9,0	0,43	9,8
	1-3-2-4-8-6-7-5	0,61	6,7	0,57	6,6	0,56	6,5	0,52	7,1	0,45	9,0	0,43	9,8
	1-3-5-2-8-6-4-7	0,59	7,2	0,56	7,0	0,55	6,8	0,52	7,1	0,45	9,0	0,43	9,8
	1-3-5-7-8-6-4-2	0,59	7,6	0,55	7,6	0,54	7,5	0,50	8,1	0,45	9,0	0,43	9,8
	1-3-7-5-8-6-2-4	0,60	6,9	0,56	6,8	0,55	6,8	0,51	7,2	0,45	9,0	0,43	9,8
	1-4-2-6-8-5-7-3	0,60	6,9	0,56	6,8	0,55	6,8	0,52	7,1	0,45	9,0	0,43	9,8
	1-4-6-2-8-5-3-7	0,59	7,6	0,59	7,4	0,54	7,2	0,52	7,1	0,45	9,0	0,43	9,8
	1-4-7-3-8-5-2-6	0,61	6,7	0,59	7,4	0,54	7,0	0,53	6,5	0,45	9,0	0,43	9,8
	1-5-7-3-8-4-2-6	0,59	7,6	0,59	7,4	0,54	7,0	0,52	7,1	0,45	9,0	0,43	9,8
	1-5-7-6-8-4-2-3	0,61	6,7	0,57	6,6	0,56	6,5	0,52	7,1	0,45	9,0	0,43	9,8
	1-6-2-4-8-3-7-5	0,59	7,6	0,59	7,4	0,54	7,0	0,52	7,1	0,45	9,0	0,43	9,8
	1-6-2-5-8-3-7-4	0,59	7,6	0,59	7,4	0,54	7,0	0,53	6,5	0,45	9,0	0,43	9,8
	1-6-4-2-8-3-5-7	0,59	7,6	0,59	7,4	0,54	7,0	0,52	7,1	0,45	9,0	0,43	9,8
	1-6-4-7-2-5-3-8	0,61	6,7	0,57	6,6	0,56	6,5	0,52	7,1	0,45	9,0	0,43	9,8
	1-7-3-5-8-2-6-4	0,59	7,6	0,59	7,4	0,54	7,0	0,52	7,1	0,45	9,0	0,43	9,8
	1-7-4-6-8-2-5-3	0,59	7,2	0,59	7,0	0,54	8,1	0,50	7,6	0,45	9,0	0,43	9,8
	1-7-5-3-8-2-4-6	0,59	7,6	0,59	7,6	0,54	7,0	0,52	7,1	0,45	9,0	0,43	9,8
	1-8-3-5-2-7-4-6	0,61	6,7	0,57	6,6	0,56	6,5	0,52	7,1	0,45	9,0	0,43	9,8
18	1-2-4-6-8-9-7-5-3	0,58	8,4	0,54	8,3	0,52	8,4	0,48	9,1	0,42	10,7	0,43	10,1
	1-3-5-7-9-8-6-4-2	0,58	8,4	0,54	8,3	0,51	8,6	0,48	8,8	0,42	10,7	0,43	10,1
	1-5-9-3-6-8-2-4-7	0,59	7,2	0,56	7,4	0,54	7,6	0,50	8,2	0,43	10,3	0,44	9,6
	1-7-4-2-8-6-3-9-5	0,59	7,1	0,56	7,0	0,54	7,3	0,50	8,2	0,43	10,3	0,44	9,6
20	1-4-3-2-5-10-7-8-9-6	0,59	7,8	0,56	7,9	0,53	8,3	0,48	9,5	0,44	10,2	0,45	9,2
	1-6-3-7-2-10-5-8-4-9	0,59	7,9	0,56	7,9	0,53	8,2	0,48	9,5	0,44	10,2	0,45	9,2
	1-6-9-8-7-10-5-2-3-4	0,58	7,8	0,54	8,1	0,51	8,4	0,48	9,3	0,44	10,2	0,45	9,2
	1-9-4-8-5-10-2-7-3-6	0,58	7,8	0,56	7,9	0,53	8,3	0,48	9,3	0,44	10,2	0,45	9,2

Table H 2.4



H 2.4

## AND C FOR 4SCSA VEE ENGINES

BETWEEN TWO CYLINDERS ON ONE PIN												FIRING ORDER PER BANK FROM FREE END OF ENGINE (EQUAL INTERVALS)	NO. OF CYLS.
270°		280°		300°		310°		315°		320°			
A	C	A	C	A	C	A	C	A	C	A	C		
0,48	4,0	0,48	4,0	0,47	3,8	0,46	3,9	0,45	4,0	0,45	4,1		4
0,48	5,8	0,45	5,4	0,43	5,7	0,41	5,6	0,42	5,7	0,42	5,5	ALL	6
0,47	4,8	0,47	4,9	0,45	4,8	0,45	4,6	0,45	4,5	0,45	4,1	ALL	8
0,39	8,4	0,37	9,4	0,37	9,1	0,37	8,3	0,38	7,5	0,38	7,5	1-2-4-5-3	10
0,39	8,4	0,37	9,4	0,37	9,0	0,36	8,2	0,38	7,8	0,38	7,4	1-3-5-4-2	
0,44	6,0	0,43	6,1	0,41	6,6	0,41	6,7	0,40	6,7	0,40	6,5	1-2-4-6-3-5	12
0,46	5,9	0,45	5,7	0,43	5,9	0,41	6,1	0,41	6,1	0,41	6,0	1-2-4-6-5-3	
0,45	5,7	0,45	5,7	0,43	5,9	0,41	6,1	0,41	6,1	0,41	6,0	1-2-5-6-4-3	
0,46	5,9	0,44	5,9	0,43	5,9	0,41	6,1	0,41	6,1	0,41	6,0	1-3-4-6-5-2	
0,45	5,7	0,45	5,7	0,43	5,9	0,41	6,1	0,41	6,1	0,41	6,0	1-3-5-6-4-2	
0,43	6,3	0,43	6,1	0,41	6,6	0,41	6,7	0,40	6,7	0,40	6,5	1-4-2-6-3-5	
0,44	6,1	0,43	6,1	0,41	6,6	0,41	6,7	0,40	6,7	0,40	6,5	1-5-3-6-2-4	
0,44	6,1	0,43	6,1	0,41	6,6	0,41	6,7	0,40	6,7	0,40	6,5	1-5-3-6-4-2	
0,43	6,8	0,41	7,8	0,35	10,2	0,33	10,7	0,33	10,6	0,33	10,1	1-2-4-6-7-5-3	14
0,43	6,6	0,41	7,6	0,35	10,1	0,33	10,9	0,33	10,5	0,33	10,1	1-3-5-7-6-4-2	
0,36	10,3	0,38	9,4	0,40	7,6	0,40	7,1	0,39	7,3	0,39	6,8	1-2-4-6-8-7-5-3	16
0,36	10,3	0,37	9,5	0,41	7,4	0,41	6,8	0,41	6,5	0,41	6,3	1-3-2-4-8-6-7-5	
0,34	11,4	0,36	10,6	0,37	8,7	0,38	8,1	0,37	7,9	0,38	7,8	1-3-5-2-8-6-4-7	
0,36	10,3	0,38	9,4	0,40	7,6	0,40	7,1	0,39	7,3	0,39	7,4	1-3-5-7-8-6-4-2	
0,36	10,3	0,38	9,4	0,40	7,6	0,40	7,1	0,39	7,0	0,39	7,0	1-3-7-5-8-6-2-4	
0,36	10,3	0,37	9,5	0,40	7,3	0,40	6,9	0,40	6,8	0,40	6,6	1-4-2-6-8-5-7-3	
0,34	11,4	0,36	10,6	0,37	8,7	0,38	8,1	0,38	7,9	0,38	7,8	1-4-6-2-8-5-3-7	
0,36	10,3	0,37	9,4	0,39	8,1	0,39	7,5	0,39	7,3	0,39	7,2	1-4-7-3-8-5-2-6	
0,36	10,3	0,37	9,4	0,39	8,1	0,39	7,5	0,39	7,3	0,39	7,2	1-5-7-3-8-4-2-6	
0,36	10,3	0,38	9,4	0,41	7,4	0,41	6,8	0,41	6,5	0,41	6,3	1-5-7-6-8-4-2-3	
0,36	10,3	0,37	9,4	0,39	8,1	0,39	7,5	0,39	7,3	0,39	7,2	1-6-2-4-8-3-7-5	
0,36	10,3	0,37	9,4	0,39	8,1	0,39	7,5	0,39	7,3	0,39	7,2	1-6-2-5-8-3-7-4	
0,33	11,6	0,35	11,9	0,37	9,1	0,38	8,1	0,37	8,1	0,37	7,9	1-6-4-2-8-3-5-7	
0,36	10,3	0,38	9,4	0,41	7,4	0,41	6,8	0,40	6,9	0,39	7,2	1-6-4-7-2-5-3-8	
0,33	11,6	0,35	11,9	0,37	9,1	0,38	8,3	0,37	8,1	0,37	7,9	1-7-3-5-8-2-6-4	
0,34	11,4	0,41	12,1	0,37	8,7	0,38	8,1	0,37	7,9	0,38	7,8	1-7-4-6-8-2-5-3	
0,34	11,4	0,36	10,6	0,37	8,7	0,38	8,1	0,37	7,9	0,38	7,8	1-7-5-3-8-2-4-6	
0,36	10,3	0,38	9,4	0,41	7,4	0,41	6,8	0,40	6,9	0,39	7,2	1-8-3-5-2-7-4-6	
0,42	7,8	0,42	7,7	0,38	9,1	0,35	10,2	0,33	10,9	0,32	11,2	1-2-4-6-8-9-7-5-3	18
0,42	7,6	0,42	7,5	0,38	9,1	0,35	10,2	0,33	10,9	0,32	11,2	1-3-5-7-9-8-6-4-2	
0,39	8,8	0,41	8,1	0,39	8,6	0,36	9,9	0,34	10,5	0,33	10,7	1-5-9-3-6-8-2-4-7	
0,39	8,8	0,41	8,1	0,39	8,6	0,36	9,9	0,34	10,5	0,33	10,7	1-7-4-2-8-6-3-9-5	
0,40	9,1	0,37	10,3	0,36	10,1	0,37	9,1	0,37	8,7	0,37	8,3	1-4-3-2-5-10-7-8-9-6	20
0,36	11,0	0,33	12,0	0,33	11,4	0,35	10,2	0,35	9,7	0,36	9,1	1-6-3-7-2-10-5-8-4-9	
0,40	9,1	0,37	10,3	0,36	10,1	0,37	9,1	0,37	8,7	0,37	8,3	1-6-9-8-7-10-5-2-3-4	
0,36	11,0	0,33	12,0	0,33	11,4	0,35	10,2	0,35	9,7	0,36	9,1	1-9-4-8-5-10-2-7-3-6	

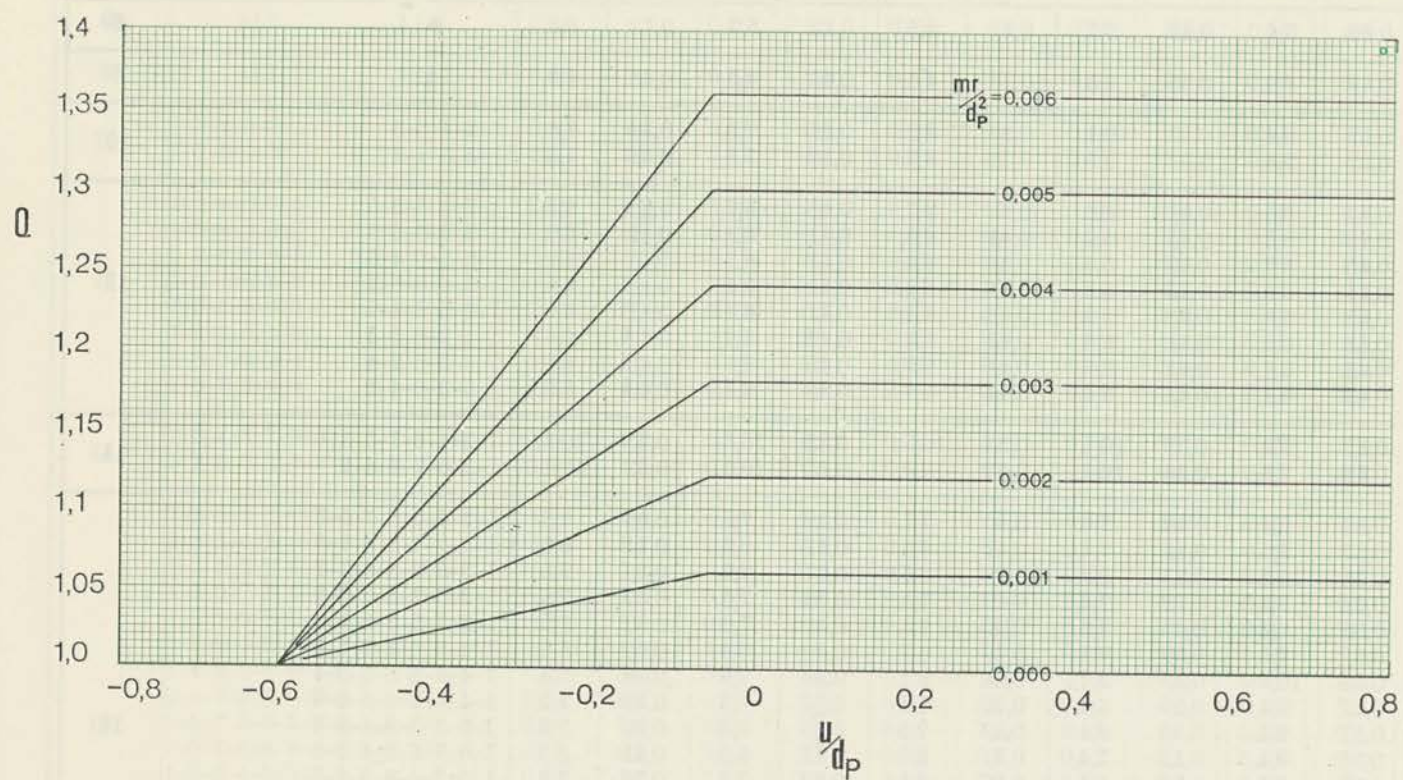


FIG. H 2.1



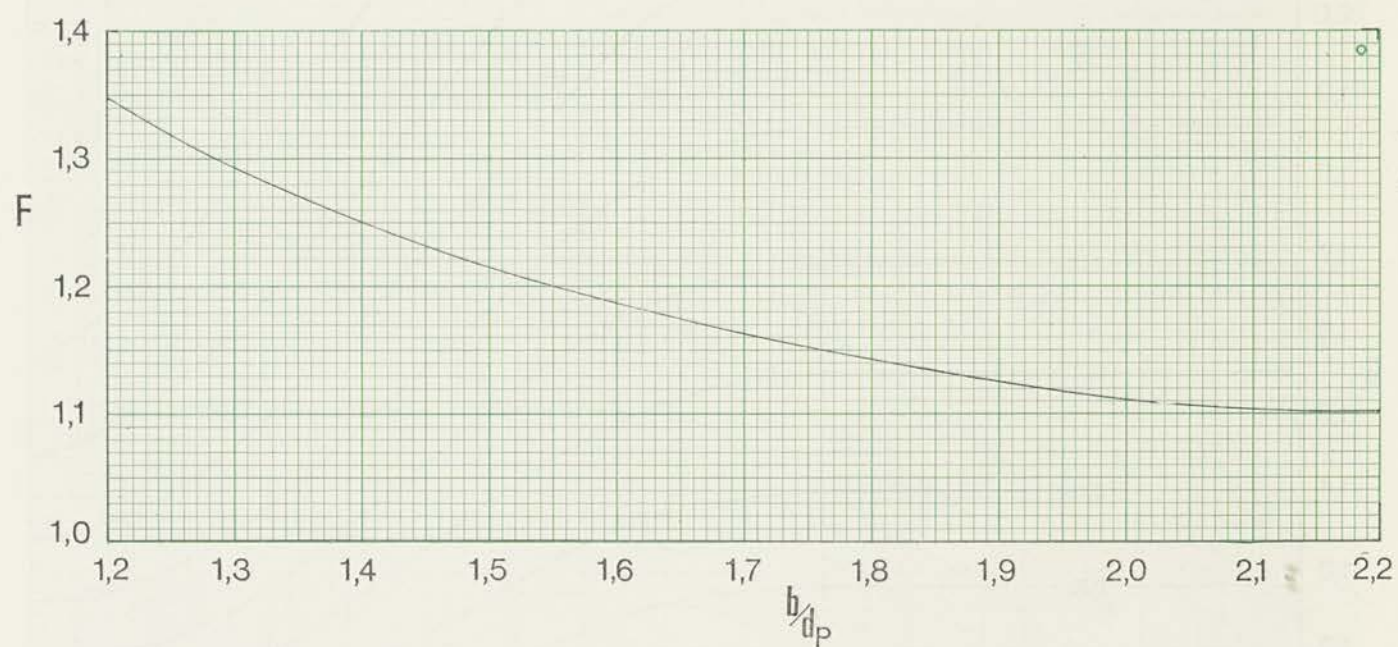


FIG. H 2.2

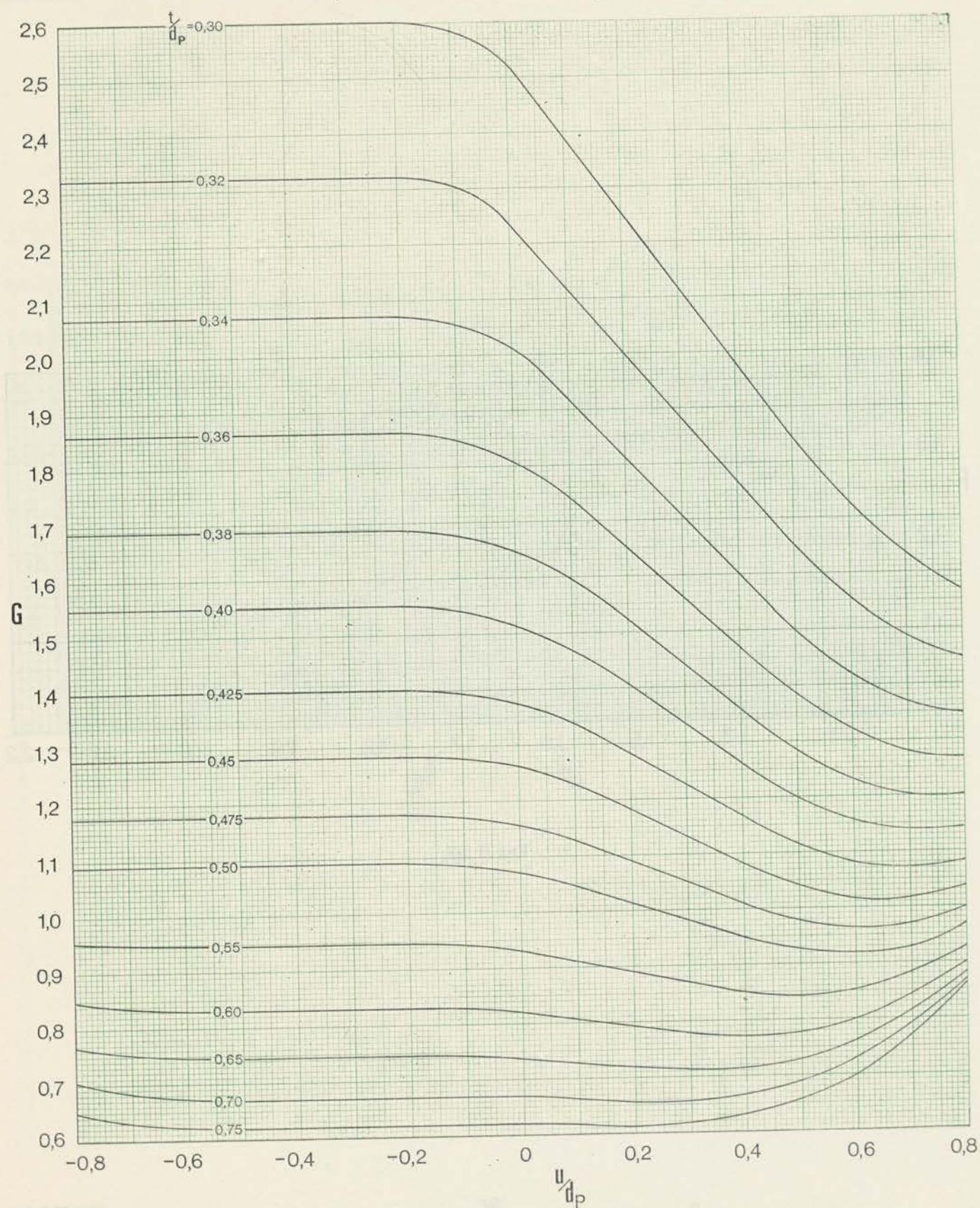


FIG. H 2.3



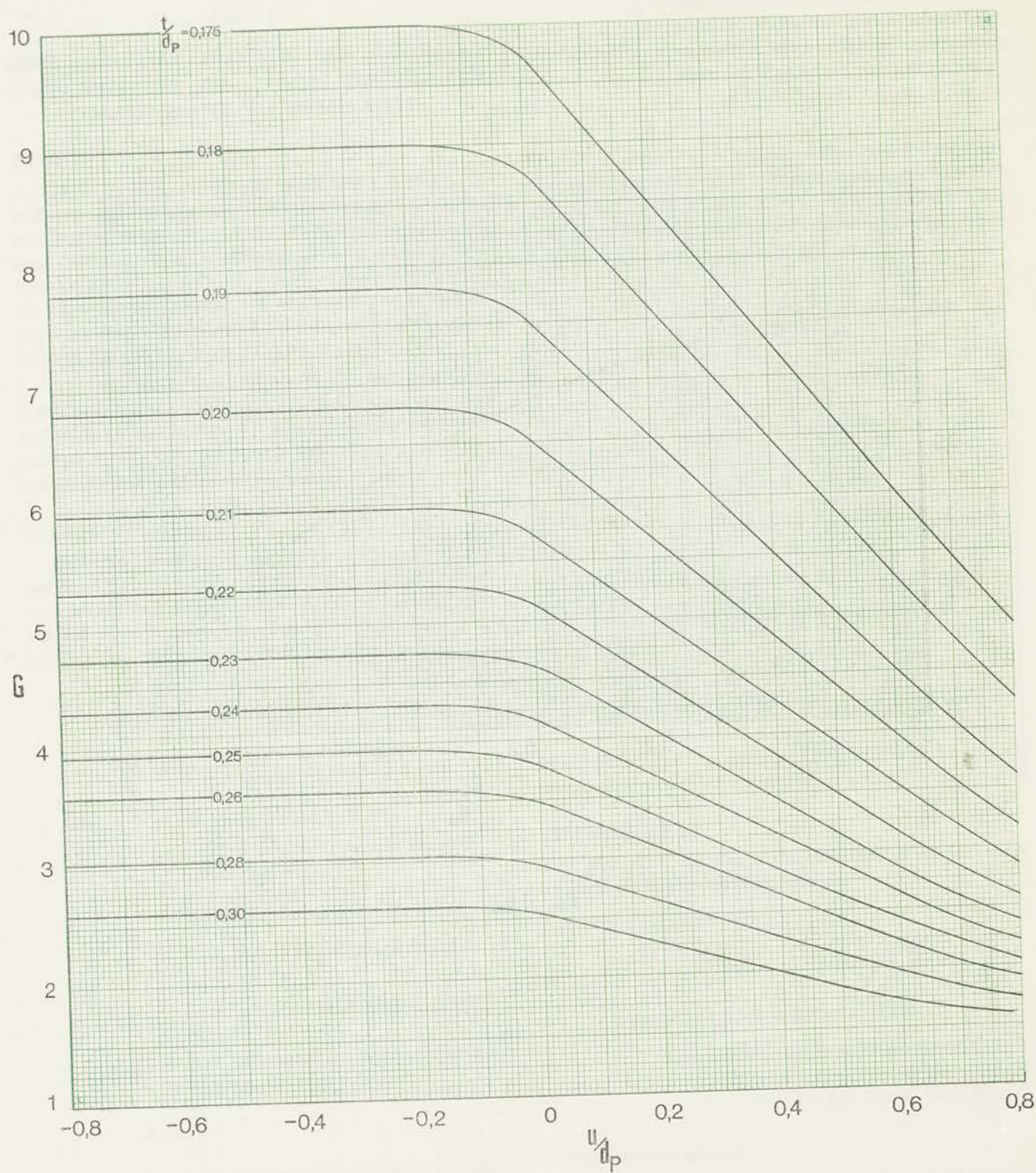


FIG. H 2.4

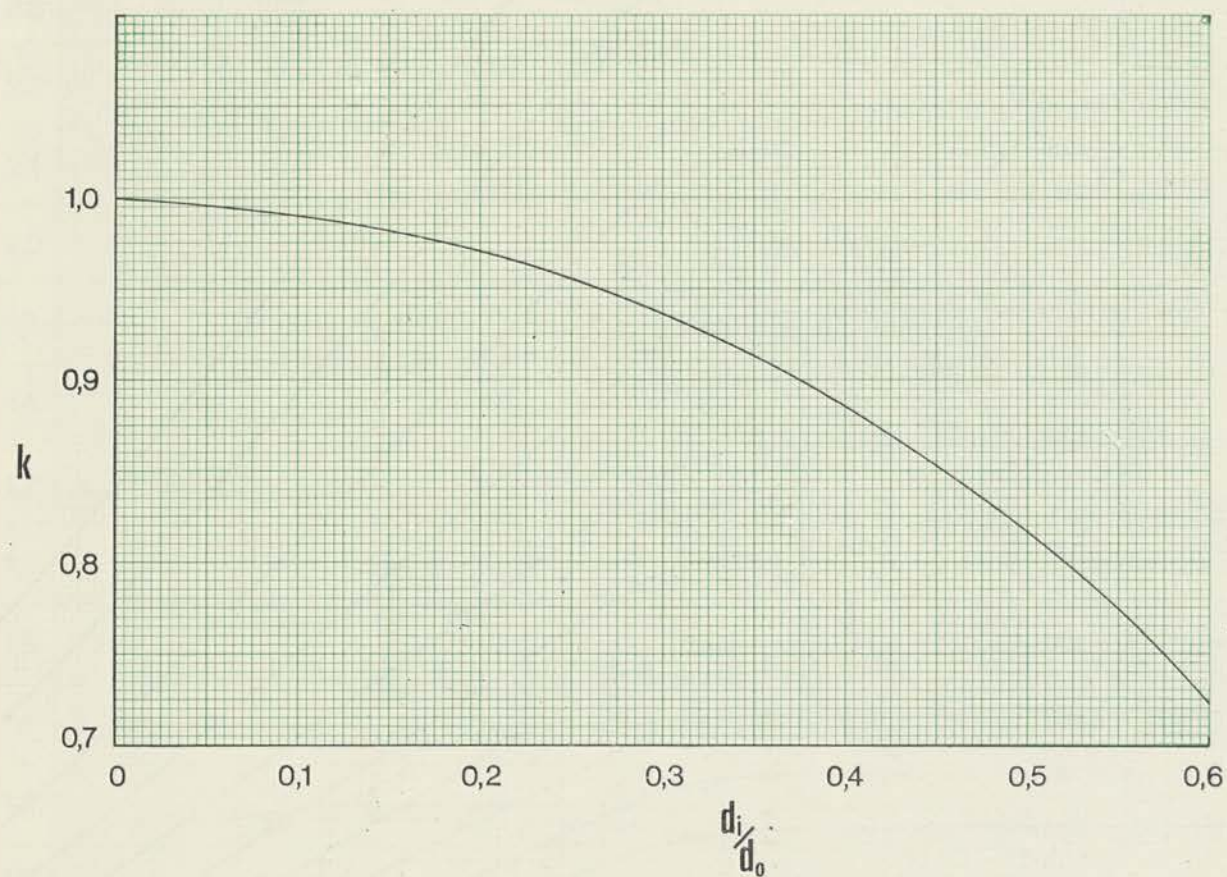


FIG. H 2.5



## PART 2

## GEAR AND LINE SHAFTING AND ASSOCIATED COMPONENTS FOR OIL ENGINE, TURBINE AND ELECTRIC PROPULSION INSTALLATIONS

## Materials

221 The intermediate and other shafts of carbon or carbon-manganese steel are to have a specified minimum tensile strength of not less than 430 N/mm<sup>2</sup> (44 kgf/mm<sup>2</sup>). Steel having a specified minimum tensile strength greater than 430 N/mm<sup>2</sup> (44 kgf/mm<sup>2</sup>) but not exceeding 780 N/mm<sup>2</sup> (80 kgf/mm<sup>2</sup>) may be used but screwshafts and tubeshafts are, in general, to be restricted to a range of tensile strength between 430 and 510 N/mm<sup>2</sup> (44 and 52 kgf/mm<sup>2</sup>).

The material is to comply with the requirements of Q 602 to Q 610 and where it is proposed to use a carbon or carbon-manganese steel having a specified minimum tensile strength greater than 590 N/mm<sup>2</sup> (60 kgf/mm<sup>2</sup>) full details are to be submitted for consideration.

## Intermediate Shaft

222 The diameter of the intermediate shaft  $d$  if of carbon or carbon-manganese steel, having a specified minimum tensile strength not less than 430 N/mm<sup>2</sup> (44 kgf/mm<sup>2</sup>) but not exceeding 780 N/mm<sup>2</sup> (80 kgf/mm<sup>2</sup>), is not to be less than determined by the following formula:—

$$d = 98,6 \sqrt[3]{C \frac{H}{R} \left( \frac{588}{T + 157} \right)} \text{ mm}$$

$$\left( d = 89 \sqrt[3]{C \frac{H}{R} \left( \frac{60}{T + 16} \right)} \text{ mm} \right)$$

where  $H$  and  $R$  are as defined in H 105,

$T$  = specified minimum tensile strength, in N/mm<sup>2</sup> (kgf/mm<sup>2</sup>),

$C = \frac{X + A}{1 + A}$  or, alternatively, the appropriate value from Table H 2.5, H 2.6 or H 2.7 for oil engines,

= 1,0 for turbines and electric propelling motors,

$X$  = ratio of maximum to mean indicated torque at the after cylinder,

$$A = \frac{J_e}{J_p}$$

$J_e$  = total mass moment of inertia of engine, including reciprocating and revolving parts and flywheel, also gearing if fitted,

$J_p$  = mass moment of inertia of propeller including entrained water referred to crankshaft speed. (Where a percentage figure for the mass of water entrained is not available, it may be taken as 25 per cent.)

NOTE. The Rule diameter of the intermediate shaft for oil engines, turbines and electric propelling motors may be reduced by 3,5 per cent for ships classed exclusively for smooth water service, and by 1,75 per cent for ships classed exclusively for service on the Great Lakes.

TABLE H 2.5  
IN-LINE ENGINES

4 STROKE SINGLE ACTING		2 STROKE SINGLE ACTING	
NUMBER OF CYLINDERS	C	NUMBER OF CYLINDERS	C
1 to 4	1,85	1 or 2	2,13
5	1,67	3	1,73
6	1,55	4	1,49
7	1,49	5	1,38
8	1,38	6	1,28
9	1,33	7	1,23
10	1,18	8	1,13
11 and over	1,04	9 and over	1,04

## Turbine Quill Shaft

223 The diameter of the quill shaft is not to be less than given by the following formula:—

Diameter of quill shaft =

$$98,6 \sqrt[3]{\frac{H}{R} \frac{430}{T}} \text{ mm} \quad \left( 89 \sqrt[3]{\frac{H}{R} \frac{44}{T}} \text{ mm} \right)$$

where  $H$  and  $R$  are as defined in H 105,

$T$  = specified minimum tensile strength of the material in N/mm<sup>2</sup> (kgf/mm<sup>2</sup>), which is not to be less than 430 N/mm<sup>2</sup> (44 kgf/mm<sup>2</sup>).

## Final Gear Wheel Shaft

224 Where there is only one pinion geared into the final wheel, or where there are two pinions which are set to



subtend an angle at the centre of the shaft of less than 120 degrees, the diameter of the shaft at the final wheel and the adjacent journals is not to be less than 1,15 times that required for the intermediate shaft.

Where there are two pinions geared into the final wheel opposite, or nearly opposite, to each other, the diameter of the shaft at the final wheel and the adjacent journals is not to be less than 1,1 times that required for the intermediate shaft.

In both the above cases, abaft the journals the shaft may be gradually tapered down to the diameter required for an intermediate shaft determined according to 222, where  $T$  is to be taken as the specified minimum tensile strength of the final wheel shaft material, in  $N/mm^2$  ( $kgf/mm^2$ ).

#### Thrust Shaft

225 The diameter at the collars of the thrust shaft transmitting torque is not to be less than 1,1 times that required for the intermediate shaft; outside a length equal to the thrust shaft diameter from the collars, the diameter may be tapered down to that required for the intermediate shaft. In determining the diameter of the intermediate shaft in accordance with 222,  $T$  is to be taken as the specified minimum tensile strength of the thrust shaft material, in  $N/mm^2$  ( $kgf/mm^2$ ).

#### Tube Shaft

226 The diameter of the tube shaft (i.e. the shaft which passes through the stern tube, but does not carry the propeller), is not to be less than 1,1 times that required for the intermediate shaft, and any part of the shaft within or without the tube which may be exposed to sea water is not to be less than 1,15 times that required for the intermediate shaft. The diameter of the intermediate shaft is to be determined in accordance with 222 and is to be based on material having a specified minimum tensile strength of 430  $N/mm^2$  (44  $kgf/mm^2$ ).

Tube shafts may have the end forward of the stern gland tapered down to a diameter, at the coupling flange, of 1,05 times that required for the intermediate shaft. Abrupt changes in shaft section at the tube shaft to intermediate shaft couplings should be avoided.

#### Screwshaft

227 The diameter of the screwshaft carrying the propeller is not to be less than given by the following formula:—

$$\text{Diameter of screwshaft, in mm} = Cd$$

where  $C = 1,236$  when the shaft is fitted with a continuous liner or is oil lubricated and provided with an approved type of oil sealing gland,

$$= 1,28 \text{ for other shafts,}$$

$d$  = diameter, in mm, required for the intermediate shaft determined in accordance with 222, based on material having a specified minimum tensile strength of 430  $N/mm^2$  (44  $kgf/mm^2$ ). For limitations on the mechanical properties of screwshaft material, see Q 606.

Screwshafts which run in sterntubes may have the end forward of the stern gland tapered down to a diameter, at the coupling flange, of 1,05 times that required for the intermediate shaft. Abrupt changes in shaft section at the screwshaft to intermediate shaft couplings should be avoided.

#### Hollow Shafts

228 Where the thrust, intermediate, and tube shafts and screwshafts have central holes, the diameters of the shafts as determined by the foregoing formulæ need not be increased, provided the diameter of the central hole in a shaft does not exceed 0,4 times the shaft diameter.

#### Couplings

229 The thicknesses of the coupling flanges at the pitch circle of the bolt holes are not to be less than the diameters of the coupling bolts at the face of the couplings as required by 230, and for this purpose the minimum tensile strength of the bolts is to be taken as equivalent to that of the shafts. The thickness, in mm, of the screwshaft coupling flange is not to be less than 0,25 of the diameter of the intermediate shaft as required by 222, based on material having a specified minimum tensile strength of 430  $N/mm^2$  (44  $kgf/mm^2$ ).

The fillet radius at the base of the coupling flange is not to be less than 0,08 of the diameter of the shaft at the coupling, but in the case of crankshafts, the fillet radius at the centre coupling flanges may be 0,05 of the diameter of the shaft at the coupling. The fillets are to have a smooth finish and should not be recessed in way of nuts and bolt heads.

All couplings which are attached to shafts are to be of approved dimensions.

Where couplings are separate from the shafts, provision is to be made to resist the astern pull.



Where a coupling is shrunk on the parallel portion of a shaft or is mounted on a slight taper, for example by means of the oil pressure injection method, full particulars of the coupling including the interference fit should be submitted for special consideration.

See paragraph 108, Chapter R (E), *Guidance Notes on Torsional Vibration Characteristics of Main and Auxiliary Oil Engines*.

### Coupling Bolts

230 The diameter of the bolts at the joining faces of the couplings is not to be less than that given by the following formula:—

$$\text{Diameter of coupling bolts} = 3,65 B \sqrt{\frac{10^6 C H}{n r T_b R}} \text{ mm}$$

$$\left( B \sqrt{\frac{10^6 C H}{n r T_b R}} \text{ mm} \right)$$

where B = 4,0 for crankshaft and thrust shaft/crankshaft couplings,

= 3,0 for other shaft couplings,

$C = \frac{X + A}{1 + A}$  or, alternatively, the appropriate

value from Tables H 2.5, H 2.6 or H 2.7 for oil engines,

= 1,0 for turbines and electric propelling motors,

X = ratio of maximum to mean indicated torque at after cylinder,

$$A = \frac{J_e}{J_p}$$

$J_e$  = total mass moment of inertia of engine, including reciprocating and revolving parts and flywheel, also gearing if fitted,

$J_p$  = mass moment of inertia of propeller including entrained water referred to crankshaft speed. (Where a percentage figure for the mass of water entrained is not available, it may be taken as 25 per cent),

n = number of bolts in the coupling,

r = radius of pitch circle of bolts, in mm,

$T_b$  = specified minimum tensile strength of bolts, in N/mm<sup>2</sup> (kgf/mm<sup>2</sup>),

H and R are as defined in H 105.

NOTE. At the joining faces of couplings, other than within the crankshaft and at the thrust shaft/crankshaft coupling, the Rule diameter of the coupling bolts may be reduced by 5,2 per cent for ships classed exclusively for smooth water service, and by 2,6 per cent for ships classed exclusively for service on the Great Lakes.

TABLE H 2.6

### 2 SCSA VEE ENGINES

NUMBER OF CYLINDERS	C FOR VARYING VEE ANGLE°				
	36	45	50	63,5	90
4	1,61	1,64	1,64	1,61	1,73
6	1,33	1,38	1,38	1,33	1,38
8	1,23	1,13	1,20	1,33	1,73
10	1,09	1,14	1,20	1,39	1,26
12	1,09	1,18	1,23	1,09	1,04
14	1,09	1,18	1,14	1,18	1,14
16	1,09	1,13	1,13	1,04	1,13
18	1,09	1,13	1,13	1,09	1,13
20	1,04	1,04	1,04	1,04	1,04

TABLE H 2.7

### 4 SCSA VEE ENGINES

NUMBER OF CYLINDERS	C FOR VARYING VEE ANGLE°					
	40	45	50	60	80	90
4	2,25	2,20	2,20	2,15	2,20	2,30
6	1,80	2,08	1,95	2,02	1,80	1,77
8	1,65	1,77	1,80	1,65	1,65	1,45
10	1,52	1,65	1,65	1,77	1,65	1,45
12	1,41	1,31	1,31	1,19	1,24	1,27
14	1,52	1,56	1,31	1,52	1,38	1,45
16	1,12	1,08	1,12	1,20	1,41	1,45
18	1,38	1,38	1,45	1,24	1,38	1,30
20	1,16	1,20	1,24	1,28	1,28	1,28



**Bronze or Gunmetal Liners on Shafts**

231 The thickness of liners fitted on screwshafts or on tube shafts, in way of the bushes, is not to be less, when new, than that given by the following formula:—

$$t = \frac{D + 230}{32} \text{ mm}$$

where  $t$  = thickness of the liner, in mm,

$D$  = diameter of the screwshaft or tube shaft under the liner, in mm.

The thickness of a continuous liner between the bushes is not to be less than 0,75  $t$ .

232 Continuous liners should preferably be cast in one piece.

Where, however, liners consist of two or more lengths, these are to be butt welded together. In general, the lead content of the gunmetal of each length forming a butt welded liner is not to exceed 0,5 per cent. The composition of the electrodes or filler rods is to be substantially lead-free.

The circumferential butt welds are to be of multi-run, full penetration type. Provision is to be made for contraction of the weld by arranging for a suitable length of the liner containing the weld, if possible about three times the shaft diameter, to be free of the shaft. To prevent damage to the surface of the shaft during welding, a strip of asbestos or other heat resisting material covered by a copper strip should be inserted between the shaft and liner in way of the joint. Other methods for welding this joint may be accepted if approved. The welding is to be carried out by an approved method and to the Surveyors' satisfaction.

Each continuous liner or length of liner is to be tested by hydraulic pressure to 0,2 N/mm<sup>2</sup> (2 kgf/cm<sup>2</sup>) after rough machining.

Liners are to be carefully shrunk on, or forced on to the shafts by hydraulic pressure. Pins are not to be used to secure the liners.

233 Effective means are to be provided for preventing water from having access to the shaft at the part between the after end of the liner and the propeller boss.

**Propeller Boss, Keys and Keyways**

234 The propeller boss is to be a good fit on the screw shaft cone. The length of the forward fitting surface should be about one diameter. The forward edge of the bore of the propeller boss is to be rounded to about a 6 mm radius.

235 Round ended or sled-runner ended type keys are to be used and the keyways in the propeller boss and cone of the screwshaft are to be provided with a smooth fillet at the bottom of the keyways. The radius of the fillet is to be at least 0,0125 of the diameter of the screwshaft at the top of the cone. The sharp edges at the top of the keyway are to be removed.

Two screwed pins should be provided for securing the key in the keyway and the forward pin should be placed at least one-third of the length of the key from the end. The depth of the tapped holes for the screwed pins should not exceed the pin diameter, and the edges of the holes should be slightly bevelled.

The distance between the top of the cone and the forward end of the keyway is not to be less than 0,2 of the diameter of the screwshaft at the top of the cone.

The effective sectional area of the key in shear, in mm<sup>2</sup>, is not to be less than  $\frac{d^3}{2,5 d_1}$

where  $d$  = diameter required for the intermediate shaft determined in accordance with 222 based on material having a specified minimum tensile strength of 430 N/mm<sup>2</sup> (44 kgf/mm<sup>2</sup>), in mm,

$d_1$  = diameter of shaft at mid-length of the key, in mm.

**Sternbush**

236 The length of the bearing in the sternbush next to and supporting the propeller is to be as follows:—

- (a) For water-lubricated bearings which are lined with lignum vitae, rubber composition or approved plastic material, the length is not to be less than four times the diameter required for the screwshaft under the liner.

Forced water lubrication is to be provided for all bearings lined with rubber or plastic and for those bearings lined with lignum vitae where the shaft diameter is 380 mm or over. The supply of water may come from a circulating pump or other pressure source. Flow indicators are to be provided for the water service to plastic and rubber bearings. The water grooves in the bearings should be of ample section and of a shape which will be little affected by wear, particularly for bearings of the plastic type.



The shut-off valve or cock controlling the supply of water is to be fitted direct to the after peak bulkhead or to the sterntube where the water supply enters the sterntube forward of the bulkhead.

- (b) For bearings which are white metal lined, oil lubricated and provided with an approved type of oil sealing gland, the length of the bearing is to be such that the nominal bearing pressure resulting from the weight of propeller and shaft will not exceed  $0,62 \text{ N/mm}^2$  ( $6,3 \text{ kgf/cm}^2$ ). In no case is the length of the bearing to be less than twice the diameter required for the screwshaft. The weight of the propeller and of screwshaft, and the type of oil sealing gland are to be stated when the plans are submitted for approval.
- (c) For bearings of cast iron and bronze which are oil lubricated and fitted with an approved oil gland, the length of the bearing is, in general, not to be less than four times the diameter required for the screwshaft.
- (d) For bearings which are grease lubricated, the length of the bearing is not to be less than four times the diameter required for the screwshaft.

Oil sealing glands fitted in ships classed for unrestricted service must be capable of accommodating the effects of differential expansion between hull and line of shafting in sea temperatures ranging from Arctic to Tropical. This requirement applies particularly to those glands which span the gap and maintain oiltightness between the sterntube and the propeller boss.

Where a tank supplying lubricating oil to the sternbush is fitted it is to be located above the load water line and is to be provided with a low level alarm device in the engine room.

Where sternbush bearings are oil lubricated, provision should be made for cooling the oil by maintaining water in the after peak tank above the level of the sterntube or by other approved means. Means for ascertaining the temperature of the oil in the sterntube should also be provided.

NOTE. Where there is compliance with the terms of (b) and (c) to the Surveyors' satisfaction a screwshaft will be assigned the notation "O.G." in the supplement to the *Register Book* for periodical survey purposes (see C 1201).

Screwshafts which are grease lubricated are not eligible for the O.G. notation.

### PART 3 SHAFT TORSIONAL VIBRATIONS & ALIGNMENT.

REVISED SEE Notice No. 1.

#### General

241 In addition to the shafting complying with the requirements of Parts 1 and 2 of this Section, where applicable, approval is also dependent on the torsional vibration characteristics of the complete shafting system(s) being found satisfactory.

Calculations of the torsional vibration characteristics of the shafting system(s) are to be prepared and submitted for consideration. Unless the responsibility for preparing and submitting this information is specifically advised, it is the responsibility of the Shipbuilder as main contractor to ensure, in co-operation with the Enginebuilders, that this information is prepared and submitted.

#### Oil Engines

242 The relevant recommendations of Chapter R (E), *Guidance Notes on Torsional Vibration Characteristics of Main and Auxiliary Oil Engines*, Section 1, should be adopted and torsional vibration calculations for the following shafting systems are to be submitted for consideration together with the associated plans, also the particulars as detailed in Table R (E) 2.1a of Section 2 of the above Guidance Notes.

(1) Main oil engine propulsion systems, except in the case of ships classed for smooth water service when fitted with engines having powers less than 110 kW (150 shp).

(2) Auxiliary oil engine machinery systems used for essential services, where the power developed by the auxiliary engines is 110 kW (150 shp) and over.

In the case of the systems referred to in (1) and (2), where critical speeds are found by calculation to show stresses approaching the limits given in Section 1 of Chapter R (E) within the range of working speeds, torsionograph records may require to be taken from the machinery for the purpose of verifying the calculations. Restricted speed ranges may be imposed on continuous running at speeds where the stresses, or the vibration torques as indicated by tooth separation and gear hammer, are considered to be excessive.

Where changes are subsequently made to a dynamic system which has been approved, e.g. by fitting a propeller of different design to the working propeller or a flexible coupling, revised torsional vibration calculations are to be submitted for consideration.

Attention is drawn to Section 2 of Chapter R (E) for the recommended method of calculation and form of submission.



**Turbines and Electric Propelling Motors**

243 With turbines or electric motors geared to the shafting and situated aft, calculations of the torsional vibration characteristics for the dynamic system formed by the turbine, motor, gearing, line shafting and propeller are to be submitted for consideration, together with plans of all shafting and propeller and details of power developed by individual turbines throughout the speed range.

Where changes are subsequently made to a dynamic system which has been approved, e.g. by fitting a propeller of different design to the working propeller, revised torsional vibration calculations are to be submitted for consideration.

Where serious critical speeds are found by calculation to occur within the range of working speeds, torsionograph records may require to be taken from the machinery for the purpose of verifying the calculations.

Restricted speed ranges may be imposed on continuous running at speeds where the vibration torques, as indicated by tooth separation and gear hammer, are considered to be excessive.

251 SEE NOTICE No. 1.

**Section 3****REDUCTION GEARING FOR PROPELLING AND AUXILIARY ENGINES****General**

301 The following requirements, except where otherwise stated, are applicable to reduction gearing for main propelling purposes and for driving electric generators where the transmitted powers exceed 220 kW (300 shp) and 110 kW (150 shp) for propulsion and auxiliary drives respectively. In any mesh, the terms pinion and wheel refer to the smaller and larger gear respectively. Bevel gears will be specially considered.

302 Particulars of the gearing are to be submitted with the plans for all propulsion gears and for auxiliary gears where the transmitted power exceeds 110 kW (150 shp), as follows:—

- Material specifications.
- Shaft horsepower and revolutions for each pinion.
- Number of teeth in each gear.
- Generating pitch diameters.
- Helix angles at generating pitch diameters.
- Normal pitches of teeth at generating pitch diameters.
- Tip diameters.
- Root diameters.
- Face widths and gaps, where applicable.

Pressure angles of teeth (normal or transverse) at generating pitch diameters.

Minimum backlash.

Centre distance.

Basic rack tooth form.

Details of post hobbing processes, if any.

Details of tooth flank corrections, if adopted.

Case depth for surface-hardened teeth.

Shrinkage allowance for shrunk-on rims and hubs.

Type of coupling proposed for oil engine applications.

**Materials**

303 The materials for pinions, pinion sleeves, wheel rims, flexible couplings and quill shafts are to be of approved composition and mechanical properties and are to comply with the requirements of Chapter Q. Manufacturer's certificates of test for materials may be accepted in cases where the transmitted power of gears is less than 110 kW (150 shp).

In the selection of materials for pinions and wheels consideration is to be given to their compatibility in operation. In general, for gears of through-hardened steels, except in the case of low reduction ratios, provision is also to be made for a hardness differential between pinion teeth and wheel teeth for which purposes the specified minimum tensile strength of the wheel rim material is not to be more than 85 per cent of that of the pinion.

When the teeth of a pinion or gear wheel are to be surface-hardened, the proposed specification together with details of the process and practice are to be submitted for approval.

**DESIGN****Symbols****304**

A = total axial length over the gear face, including gap, where applicable, in mm,

C = distance between centrelines of pinion and wheel shafts, in mm,

d and D = pitch circle diameter of pinion and wheel respectively, in mm,

$$= \frac{2 C z_1}{z_1 + z_2} \text{ and } \frac{2 C z_2}{z_1 + z_2} \text{ respectively,}$$

$d_a$  and  $D_a$  = tip diameter of pinion and wheel respectively, in mm,

$d_b$  and  $D_b$  = base diameter of pinion and wheel respectively, in mm,

$d_o$  and  $D_o$  = root diameter of pinion and wheel respectively, in mm,



$d_s$  and  $D_s$  = shrinkage surface diameter of pinion and wheel rims respectively, in mm,

$F$  = total axial length over the gear face, less gap, where applicable, in mm,

$G$  = gear ratio =  $\frac{\text{pinion speed}}{\text{wheel speed}}$   
 $= \frac{\text{number of teeth in wheel}}{\text{number of teeth in pinion}}$

$h$  = total depth of tooth, in mm,

$H = F$  for single helical and spur gears or  $\frac{F}{2}$  for double helical gears, in mm,

$L$  = length of line of action,  
 $= \frac{1}{2}\sqrt{d_a^2 - d_b^2} + \frac{1}{2}\sqrt{D_a^2 - D_b^2} - C \sin \alpha_{tw}$ ,  
 in mm, for external gears, and  
 $= \frac{1}{2}\sqrt{d_a^2 - d_b^2} - \frac{1}{2}\sqrt{D_a^2 - D_b^2} + C \sin \alpha_{tw}$ ,  
 in mm, for internal gears,

$N$  = revolutions per minute of pinion divided by 1000,

$P$  = radial pressure at shrinkage surface of rim, in  $N/mm^2$  ( $kgf/mm^2$ ),

$p_n$  = normal pitch of teeth, in mm,

$r$  = tooth fillet radius, in mm,

$T$  = specified minimum tensile strength of gear material, in  $N/mm^2$  ( $kgf/mm^2$ ),

$W$  = maximum permissible tangential tooth load, in  $N/mm$  ( $kgf/mm$ ), of overall face width, less gap where applicable,

$x$  = addendum modification coefficient for gear under consideration,

$z$  = number of teeth in gear under consideration, ( $z_1$  for pinion,  $z_2$  for wheel),

$z_n$  = virtual number of teeth in gear under consideration =  $z \sec^3 \beta$

$\alpha_n$  = pressure angle, in degrees, in normal section at generating pitch diameter,

$\alpha_t$  = pressure angle, in degrees, in transverse section at generating pitch diameter,

$\alpha_{tw}$  = working pressure angle, in degrees, in transverse section,

$\beta$  = helix angle, in degrees, at generating pitch diameter,

$\beta_b$  = helix angle, in degrees, on base cylinder,

$\varepsilon_\alpha$  = transverse contact ratio =  $\frac{L \cos \beta}{p_n \cos \alpha_t}$ ,

$\varepsilon_\beta$  = overlap ratio =  $\frac{H}{p_n} \sin \beta$ .

### Tooth Form

**305** The tooth profile in the transverse section is to be of involute shape, and the roots of the teeth are to be formed with smooth fillets of radii not less than 8 per cent of the normal pitch.

For propulsion gears, where the ratio  $F/d$  exceeds 1.5, the ends of the pinion and wheel teeth are to be cut back from the root at an angle of  $45^\circ$  to  $60^\circ$  to the pitch line, and the ends of helical teeth are to be suitably tapered. The tapering of helical teeth may be omitted, provided that appropriate measures to counteract pinion deflection have been taken.

The teeth of pinions and wheels are to be suitably relieved on flanks in cases where any of the following conditions apply:—

Normal pitch of teeth exceeds 20 mm.

Addendum of pinion teeth exceeds 65 per cent of total working depth of engagement.

Ratio of total working depth of engagement to normal pitch of teeth exceeds 0.75.

All sharp edges left on the tips and ends of pinion and wheel teeth after hobbing and finishing are to be removed.

### Tooth Loading for Surface Stress

**306** In order to limit the tooth surface stress, the tooth load for the proposed power rating (see H 105) is not to exceed that given by the following formula:—

$$W = K d \frac{G}{(G+1)} N/mm \text{ (kgf/mm)}$$

where  $K$  = loading factor derived as follows:—

$$K = \left( \frac{5850 + dN}{3\,040\,000} \right) K_1 K_2 K_3 B S^2,$$

$$\left( K = \left( \frac{5850 + dN}{310\,000} \right) K_1 K_2 K_3 B S^2 \right),$$

$$K_1 = \frac{\cos^2 \alpha_t \sin \alpha_{tw}}{\cos \beta_b \cos \alpha_{tw}},$$

$K_2$  = value according to Table H 3.1,

$$K_3 = 1 - \frac{1}{16} \left( \frac{A}{d} \right)^2, \text{ or}$$

$$= 1 - \frac{1}{90} \left( \frac{A}{d} \right)^3 \text{ where appropriate measures to counteract pinion deflection have been provided,}$$

$$B = \varepsilon_{\alpha}, \text{ for } \varepsilon_{\beta} \geq 1$$

$$= \frac{1}{2} \left[ \varepsilon_{\alpha}(1 + \varepsilon_{\beta}) + (1 - \varepsilon_{\beta}) \right] \text{ for } \varepsilon_{\beta} < 1$$

S = value according to Table H 3.2,

T = lower value of specified minimum tensile strength of pinion or wheel, in N/mm<sup>2</sup> (kgf/mm<sup>2</sup>).

Where the teeth of gears are subjected to an approved post hobbing process, or profile-ground, or where it can be demonstrated in advance that the finish and profile of the teeth are equivalent, the permissible loading may be increased by up to 33 per cent.

For surface-hardened gears, the full depth of the hardened zone, i.e. depth to core hardness, is to comply with Q 627(h), but is in no case to be less than:—

$$\frac{2,17 d}{1000} \frac{G}{G+1} \sqrt{\frac{K \tan \alpha_{tw}}{\varepsilon_{\alpha} \cos \beta_b}} \text{ mm}$$

$$\left( \frac{6,8 d}{1000} \frac{G}{G+1} \sqrt{\frac{K \tan \alpha}{\varepsilon_{\alpha} \cos \beta_b}} \text{ mm} \right)$$

where K is derived from the proposed loading.

#### Tooth Loading for Bending Stress

307 In order to limit the bending stress at the root section of gear teeth for the proposed power rating (see H 105), the fillet radius should be blended smoothly into the involute profile, and the tooth load for either pinion or

TABLE H 3.1

VALUES OF $K_2$ AND $Y_1$		
TURBINE PROPULSION GEARS	PRIMARY	SECONDARY
Tandem	1,00	0,88
Dual tandem	0,93	0,81
Tandem articulated	1,10	0,97
Dual tandem articulated	1,02	0,97
SINGLE AND DOUBLE REDUCTION OIL ENGINE PROPULSION GEARS	SINGLE ENGINE DRIVE	MULTI-ENGINE DRIVE
Hydraulic coupling or equivalent on input	1,10	0,97
High-elastic coupling on input	1,00	0,88
Other couplings	0,85	0,74
ALL AUXILIARY GEARS	1,30	

NOTE. A "high-elastic coupling" is one providing sufficient torsional, axial and angular flexibility to the particular installation to minimize the effect of load variations and malalignment on the load sharing of the gear teeth.

TABLE H 3.2

HEAT TREATMENT		S	
PINION	WHEEL	SI value	Metric value
Through-hardened	Through-hardened	$\frac{T}{100} + 16,67$	$\frac{T}{100} + 1,70$
Surface-hardened	Through-hardened	$\frac{T}{110} + 24,03$	$\frac{T}{110} + 2,45$
Carburized, nitrided or induction-hardened	Tufftrided	45,6	4,65
Carburized, nitrided or induction-hardened	Induction-hardened	50,5	5,15
Nitrided	Nitrided	50,5	5,15
Carburized	Carburized	58,84	6,00



wheel is not to exceed that given by the following formula:—

$$W = \frac{Y_1 Y_2 Y_3 \varepsilon \alpha}{1100 Y_4 Y_5 Y_6} \left( 13\,000 - dN \right) \frac{U p_n^2}{h} \text{ N/mm (kgf/mm)}$$

where  $Y_1$  = value according to Table H 3.1,

$$Y_2 = 1 - \frac{1}{16} \left( \frac{A}{d} \right)^2, \text{ or}$$

$$= 1 - \frac{1}{90} \left( \frac{A}{d} \right)^3 \text{ where appropriate measures to counteract pinion deflection have been provided,}$$

$$Y_3 = \sqrt{\frac{J+x}{J}} \text{ for external gears, and}$$

$$= \sqrt{\frac{J-x}{J}} \text{ for internal gears,}$$

$$J = \frac{z_n + 13}{31,3}$$

$$Y_4 = \left( 51 - \alpha_n \right) \left( 1 + \frac{22}{3z_n} \right) \left( 1 - \frac{2r}{p_n} \right)$$

for external gears, and

$$= \left( 51 - \alpha_n \right) \left( 1 - \frac{2r}{p_n} \right) \text{ for internal gears,}$$

$$Y_5 = 120 - \beta$$

where  $\beta$  (as defined in 304) is not to be taken for calculation as greater than  $30^\circ$ ,

$$Y_6 = 1 \text{ for fabricated pinions and wheels, and for pinions and wheels integral with shafts,} \\ = 1,25 \text{ for shrunk-on pinions and wheel rims, alternatively, where } W \text{ is the proposed tooth load,}$$

$$Y_6 = 1 + \frac{1,96 d_s^2 d P}{W U (d_o^2 - d_s^2)}$$

$$\left( Y_6 = 1 + \frac{0,2 d_s^2 d P}{W U (d_o^2 - d_s^2)} \right)$$

for shrunk-on pinion rims, and

$$Y_6 = 1 + \frac{1,96 D_s^2 D P}{W U (D_o^2 - D_s^2)}$$

$$\left( Y_6 = 1 + \frac{0,2 D_s^2 D P}{W U (D_o^2 - D_s^2)} \right)$$

for shrunk-on wheel rims,

$$U = \text{value according to Table H 3.3.}$$

For an idler gear,  $Y_4$  should be increased by 50 per cent.

Where the teeth of gears are subjected to an approved post-hobbing process, or profile-ground, or where it can be demonstrated in advance that the finish and profile of the teeth are equivalent, the permissible loading may be increased by up to 20 per cent.

TABLE H 3.3

HEAT TREATMENT	U	
	SI value	Metric value
Through-hardened carbon steel	T+1274,9	T+130
Through-hardened alloy steel	T+1569,1	T+160
Tufftrided	2942,0	300
Nitrided or induction-hardened	3187,2	325
Carburized, hardened	3530,4	360

## CONSTRUCTION

## Gear Wheels and Pinions

308 Where wheels are of cast construction any radial slots in the periphery are to be fitted with permanent chocks before shrinking-on the rim.

When bolts are used to secure side plates to rim and hub, the bolts are to be a tight fit in the holes and the nuts are to be suitably locked by means other than welding.

When welding is employed in the construction of wheels, the welding procedure is to be approved in the first instance by the Surveyors before work is commenced. For this purpose, test specimens representative of the welded joints used in the construction of the wheel are to be provided for examination and mechanical test. Sections are also to be taken from the test joints at positions selected by the Surveyors, and are to be macro-etched to verify that the welds are sound. Wheels are to be stress relieved after welding. All welds are to have a smooth surface and even contour and are to be proved by magnetic crack detection methods.

In general, arrangements are to be made so that the interior structure of the wheel may be examined. Alternative proposals will be specially considered.

## Accuracy of Gear Cutting and Alignment

309 Gearing is to be cut only on machines which are maintained at a high standard of accuracy. When large gears are designed with loading factors exceeding  $K = 0,55$  (0,056), any hobbing machines used in their production are to operate under conditions of temperature control with a total temperature variation not exceeding  $2^\circ\text{C}$  for the finishing cut. The blank should be allowed sufficient time to stabilize to the machine temperature before cutting commences.



The accuracy of gear-cutting of pinions and wheels is to be demonstrated to the satisfaction of the Surveyors. For this purpose, records of measurements of pitch errors undulations, axial pitch errors, tooth thickness and backlash should be available for review by Surveyors on request.

The alignment is to be demonstrated in the workshop by meshing in the gearbox without oil clearance in the bearings, or in the meshing frame without oil clearance in the bearings, or on rollers. Meshing is to be carried out with the gears locating in their load positions, and a load sufficient to overcome pinion weight and axial movement is to be imposed.

The gears are to be suitably coated to demonstrate the contact marking on each helix. This should not be less than the following amounts:—

For through-hardened gears, 40 per cent of the working depth for 35 per cent of the length and 20 per cent of the working depth for a further 35 per cent of the length.

For through-hardened gears where the increase in loading permissible for surface finish in 306 and 307 is required and for all surface-hardened gears, 40 per cent of the working depth for 50 per cent of the length and 20 per cent of the working depth for a further 40 per cent of the length.

#### Balance of Gear Pinions and Wheels

**310** All pinions, gear wheels and flexible couplings or sleeves whose maximum designed speed of rotation exceeds 1000 revolutions per minute are to be dynamically balanced. Where the speed of rotation is 1000 revolutions per minute or less, these components are to be statically or, alternatively, dynamically balanced. Parts of couplings, etc., which are to be fixed to the gear in service shall normally be attached before balancing.

The final out of balance of each assembly at the balancing planes should not exceed 677 N mm/tonne (69 kgf mm/tonne) for static balancing. For dynamic balancing the final out of balance should not exceed

$$\frac{190\,250}{N_1} \text{ N mm/tonne} \quad \left( \frac{19\,400}{N_1} \text{ kgf mm/tonne} \right)$$

where  $N_1$  = revolutions per minute appropriate to the assembly.

Balancing may, however, be omitted for turbine secondary pinions and for oil engine gearing, provided that the rotating components are of solid forged construction or have a solid forged centre with shrunk-on rim, and in both

cases are machined to give a concentric and uniform cross-section.

#### Gearcases

**311** Gearcases and their supports are to be designed sufficiently stiff such that misalignment at the mesh due to movements of the external foundations and the thermal effects under all conditions of service do not disturb the overall tooth contact. If welding is employed in their construction they are to be stress relieved on completion (see also H 108).

Inspection openings are to be provided at the peripheries of gearcases to enable the teeth of pinions and wheels to be readily examined. Where the construction of gearcases is such that sections of the structure cannot readily be moved for inspection purposes, access openings of adequate size are also to be provided at the ends of the gearcases to permit examination of the structure of the wheels. Their attachment to the shafts is to be capable of being examined by removal of bearing caps or by equivalent means.

#### Trials

**312** Prior to full power sea trials, the teeth are to be suitably coated to demonstrate the contact marking on each helix.

The sea trials are to be of sufficient duration to prove the gears. On conclusion, all gears are to be opened up sufficiently to permit the Surveyors to make an inspection of the teeth.

After these trials, the marking revealed by inspection is to indicate freedom from hard bearing particularly towards both ends of each helix.

The contact across the profile is not to be less than that required in H 309.

In the case of through-hardened gears, not less than 70 per cent contact across the effective face width should be indicated. Where the teeth of such gears are finished by an approved post-hobbing process, or profile-ground, or where it can be demonstrated in advance that the finish and profile of the teeth are equivalent, and the increase in loading permitted by 306 and 307 is required, not less than 90 per cent contact across the effective face width should be indicated.

For surface-hardened gears, the contact across the effective face width should also be not less than 90 per cent.

#### Cross-reference

**313** For lubricating oil systems, see E 9.



## Section 4

## PROPELLERS

## Materials

401 Where bronze or cast steel is used for propellers or propeller blades, the materials should comply with the relevant requirements of Chapter Q, or an approved specification.

Cast iron propellers are to be made of a high duty iron of at least 260 N/mm<sup>2</sup> (27 kgf/mm<sup>2</sup>) tensile strength, or of a nodular or spheroidal graphite ductile type cast iron.

402 A plan, in triplicate, of the propeller is to be submitted for approval, together with the following particulars:—

Maximum blade thickness of the expanded cylindrical section considered

Maximum shaft power (see H 105)

Revolutions per minute of the propeller at maximum power  
Propeller diameter

Pitch at 25 per cent radius (for solid propellers only)

Pitch at 35 per cent radius (for controllable pitch propellers only)

Pitch at 60 per cent radius

Pitch at 70 per cent radius

Length of blade section of the expanded cylindrical section at 25 per cent radius (for solid propellers only)

Length of blade section of the expanded cylindrical section at 35 per cent radius (for controllable pitch propellers only)

Length of blade section of the expanded cylindrical section at 60 per cent radius

Rake at blade tip measured at shaft axis (backward rake positive, forward rake negative)

Number of blades

Developed area ratio

Material: Chemical composition, also mechanical properties and density (if not included in Table H 4.1)

NOMENCLATURE AND UNITS  
TO BE USED IN FORMULAE

T in mm

H in kW (shp)

R

D in metres

P<sub>0,25</sub> in metres

P<sub>0,35</sub> in metres

P<sub>0,6</sub> in metres

P<sub>0,7</sub> in metres

L<sub>0,25</sub> in mm

L<sub>0,35</sub> in mm

L<sub>0,6</sub> in mm

A in mm

N

B

## Minimum Blade Thickness

403 The thickness of the propeller blades at the root (25 per cent radius for solid propellers, 35 per cent radius for controllable pitch propellers) neglecting any increase due to fillets, and at 60 per cent radius is not to be less than:—

$$T = \frac{9,81 \text{ KCA}}{E F U L N} + 36,27 \sqrt{\frac{24\,000 M H}{E F R U L N}} \text{ mm}$$

$$\left( T = \frac{\text{KCA}}{E F U L N} + 9,93 \sqrt{\frac{24\,000 M H}{E F R U L N}} \text{ mm} \right)$$

where L = L<sub>0,25</sub>, L<sub>0,35</sub> or L<sub>0,6</sub> as appropriate,

$$K = \frac{G B D^3 R^2}{6600}$$

G and U = material values (see Table H 4.1).

The value U may be increased by 10 per cent for twin screw and outboard propellers of triple screw ships.

For cases where the composition of the propeller material is not specified in Table H 4.1, or where propellers of the cast irons and carbon and low alloy steels shown in this Table are provided with an approved method of cathodic protection, special consideration will be given to the value of U.

E = 1 for aerofoil sections with trailing edge wash-back,

E = 1,25 for aerofoil sections without trailing edge washback.

For other blade section shapes, the value of E may be adjusted in the ratio:

$$\frac{\text{actual face modulus}}{0,09 \text{ T}^2 \text{ L}}$$

For solid propellers at 25 per cent radius:—

$$C = 1$$

$$F = \frac{P_{0,25}}{D} + 0,8$$

$$M = 1 + \frac{3,75 D}{P_{0,7}} + 2,8 \frac{P_{0,25}}{D}$$

For controllable pitch propellers at 35 per cent radius:—

$$C = 1,4$$

$$F = \frac{P_{0,35}}{D} + 1,6$$

$$M = 1,35 + \frac{5 D}{P_{0,7}} + 2,6 \frac{P_{0,35}}{D}$$

TABLE H 4.1

MATERIAL	SI			METRIC		
	Specified Minimum Tensile Strength N/mm <sup>2</sup>	G Density g/cm <sup>3</sup>	U Allowable Stress N/mm <sup>2</sup>	Specified Minimum Tensile Strength kgf/mm <sup>2</sup>	G Density g/cm <sup>3</sup>	U Allowable Stress kgf/mm <sup>2</sup>
Cast Iron (Grey or Low Alloy)	260	7,2	17,2	27	7,2	1,75
Spheroidal Graphite or Nodular Cast Iron	430	7,3	20,6	44	7,3	2,1
Carbon and Low Alloy Steels	430	7,9	20,6	44	7,9	2,1
13% Chromium Stainless Steels	540	7,7	41,2	55	7,7	4,2
Chromium-Nickel Austenitic Stainless Steels	540	7,9	41,2	55	7,9	4,2
A1. Manganese Bronze (high tensile brass)—low nickel	460	8,3	43,1	47	8,3	4,4
A2. Manganese Bronze (high tensile brass)—high nickel	460	8,3	43,1	47	8,3	4,4
B1. Aluminium Bronze—high manganese	630	7,5	51,0	64	7,5	5,2
B2. Aluminium Bronze—high nickel	630	7,7	55,9	64	7,7	5,7

For all propellers at 60 per cent radius:—

$$C = 1,6$$

$$F = \frac{P_{0,6}}{D} + 4,5$$

$$M = 1,35 + \frac{5D}{P_{0,7}} + 1,35 \frac{P_{0,6}}{D}$$

For propellers of unusual design, or where the propeller is intended for more than one operating regime, such as towing or trawling, a detailed stress computation for the blades is to be submitted for consideration.

### Section 5

#### STRENGTHENING FOR NAVIGATION IN ICE (GENERAL SERVICE)

##### General

501 Where the notation "Ice Class 1\*, 1, 2 or 3" as specified in B 12 9(a) is desired, the following requirements are to be complied with, so far as these are applicable.

(For northern Baltic service see H 5A.)

#### Power of Propelling Machinery

502 The power delivered to the propeller shafting, in kW (shp), is not to be less than C L B

where L = length of ship, between perpendiculars, in metres,

B = breadth of ship, moulded, in metres,

C = 1,54 (2,10) for Class 1\*

1,32 (1,79) for Class 1

0,96 (1,31) for Class 2

0,72 (0,98) for Class 3.

#### Turbines

503 Where turbines are used for the propulsion of ships intended for Class 1\*, 1 or 2 ice strengthening, the propeller shafting is to be driven by electrical or other approved means capable of protecting the turbines from shock.



**Electric Motors**

504 Where direct current electric motors are used for the propulsion of ships intended for Class 1\*, 1 or 2 ice strengthening, provision is to be made for automatically limiting the transmitted torque to a safe value.

**Materials**

505 The propulsion shafting is to be of steel and the associated couplings are to be of steel or other approved material. For the material of screwshafts, see Q 601 to Q 610.

506 Propellers and propeller blades are to be of cast steel or bronze having specified minimum tensile strengths as stated in Table H 4.1 and are to comply with the requirements of Q 5 or Q 9, as applicable.

**Main Engine Shafting, Gearing and Propellers**

507 The diameters of the shafting as required by the rules for ocean-going service are to be increased by the percentages stated in Table H 5.1. No increase in the diameter of crankshafts of oil engines is required.

If gearing is fitted between the engine and propeller shafting, the gearing is to be designed and constructed to transmit torque in excess of that corresponding to the engine power by the percentages given in Table H 5.1.

The thicknesses of the blades at the root and at 60 per cent radius as required by H 403 are to be increased by the percentages stated in Table H 5.1.

TABLE H 5.1

AMENDED SEE NOTICE No. 1

CLASS	1*	1	2	3
Gearing, torque increase ...	50%	25%	15%	—
Thrust and intermediate shaft, increase in diameter ...	12%	8%	4%	—
Screwshaft, increase in diameter ...	20%	15%	8%	5%
Propeller, increase in blade thickness ...	35%	25%	15%	8%

**Minimum Propeller Blade Tip Thickness**

508 The tip thickness  $t$  of the blade at 95 per cent radius is not to be less than that obtained by the following formula for Class 1\*, 1, 2 and 3 ice strengthening:—

$$t = 0,14 (T + 57) \sqrt[3]{\frac{430}{S}} \text{ mm}$$

$$\left( t = 0,14 (T + 57) \sqrt[3]{\frac{44}{S}} \text{ mm} \right)$$

where  $T$  = blade root thickness required for appropriate Class, in mm,

$S$  = specified minimum tensile strength of material, in  $\text{N/mm}^2$  ( $\text{kgf/mm}^2$ ).

The edges of the blades are to be suitably thickened for the operating conditions but are not to be less than 50 per cent of the required tip thickness  $t$ , measured at 1,25 times tip thickness  $t$  from the edge. For controllable pitch propellers, this requirement need only be applied to the loading edges of the blades.

**Ship-side Valves**

509 The sea inlet and overboard discharge valves which are situated at or below the maximum load line, are to be provided with a low pressure steam or compressed air connection for clearing purposes, see E 267 and E 271.

Where steam is not available for clearing, it is recommended that arrangements be made for supplying water for machinery cooling purposes by circulating from ballast tank(s) of adequate capacity preferably situated in the double bottom. Such tank(s) are to be used only for storage of water ballast or fresh water.

510 Connections are to be fitted between the cooling water overboard discharge lines and sea inlets for main and auxiliary engine cooling water systems so that warm water may be used to assist in maintaining the suction pipes free from ice.

Where the cooling water inlet valves are fitted to a common water box, the connections from the cooling water discharge lines may be led to the water box in a position as near as possible to the inlet valves.

511 In motor ships where clearing steam is not available, fire pumps are to be provided with suctions from the main cooling water inlet pipe.

**Cross-references**

512 For hull requirements, see D 24, and for general requirements for ship-side valves, see E 267 to E 271.



## Section 5A

STRENGTHENING FOR NAVIGATION IN ICE  
(NORTHERN BALTIC SERVICE)

## General

520 Where the notation "Ice Class IA Super, IA, IB or IC" as specified in B 129 (b), is desired, the following requirements are to be complied with, so far as these are applicable.

## Definitions

521 The displacement,  $V$ , is that related to the summer load line assigned, in tonnes. (Relative density of water = 1,0.)

## Power of Propelling Machinery

522 For the different ice classes, the shaft power,  $H$ , is not to be less than that determined by the following formulæ, and is not to be less than 735 kW (1000 shp) for any ice class and not less than ~~2513~~ 3513 kW (3500 shp) for Ice Class IA Super. The minimum required shp and the lower limits may be reduced by 10 per cent, if the ship is fitted with a controllable pitch propeller and reversible main machinery. For a ship fitted with steam turbines the astern power is to be at least 70 per cent of the ahead power.

## Ice Class IA Super

$$H = 0,294 V + 1103; \text{ but need not exceed } 18\,755 \\ (H = 0,40 V + 1500; \text{ but need not exceed } 25\,500.)$$

## Ice Class IA

$$H = 0,257 V + 735; \text{ but need not exceed } 16\,180 \\ (H = 0,35 V + 1000; \text{ but need not exceed } 22\,000.)$$

## Ice Class IB

$$H = 0,221 V + 368; \text{ but need not exceed } 13\,607 \\ (H = 0,30 V + 500; \text{ but need not exceed } 18\,500.)$$

## Ice Class IC

$$H = 0,184 V; \text{ but need not exceed } 11\,033 \\ (H = 0,25 V; \text{ but need not exceed } 15\,000.)$$

where  $V$  is as defined in 521.

## Determination of Ice Torque

523 Dimensions of propellers, shafting and gearing are determined by formulae taking into account the impact when a propeller blade hits ice. The ensuing load is herein-after defined by the ice torque  $M$ .

$$M = m D^2 \text{ kN m (tonne-f m)}$$

where  $D$  = diameter of propeller, in metres, and

$$m = 21,10 \text{ (2,15) for Ice Class IA Super} \\ = 15,69 \text{ (1,60) for Ice Class IA} \\ = 13,04 \text{ (1,33) for Ice Class IB} \\ = 11,96 \text{ (1,22) for Ice Class IC}$$

If the propeller is not fully submerged when the ship is in ballast condition, the ice torque for Ice Class IA is to be used for Ice Classes IB and IC.

## Propellers

524 For steel propellers the elongation of the material used is not to be less than 19 per cent for a test piece length = 5  $d$ , and the value for the Charpy V-notch test is not to be less than 21 J (2,1 kgf m) at  $-10^\circ\text{C}$ . See also Q 5.

525 Width  $L$  and thickness  $T$  of propeller blade sections are to be determined so that:—

(a) at the radius  $0,25 D/2$ , for solid propellers

$$LT^2 \geq \frac{26\,478\,000}{S(0,65 + 0,7 P/D)} \left( 27,2 \frac{H}{NR} + 2,24 M \right) \\ \left( LT^2 \geq \frac{2\,700\,000}{S(0,65 + 0,7 P/D)} \left( 20 \frac{H}{NR} + 22 M \right) \right)$$

(b) at radius  $0,35 D/2$  for controllable pitch propellers

$$LT^2 \geq \frac{21\,084\,300}{S(0,65 + 0,7 P/D)} \left( 27,2 \frac{H}{NR} + 2,35 M \right) \\ \left( LT^2 \geq \frac{2\,150\,000}{S(0,65 + 0,7 P/D)} \left( 20 \frac{H}{NR} + 23 M \right) \right)$$

(c) at the radius  $0,6 D/2$

$$LT^2 \geq \frac{9\,316\,320}{S(0,65 + 0,7 P/D)} \left( 27,2 \frac{H}{NR} + 2,86 M \right) \\ \left( LT^2 \geq \frac{950\,000}{S(0,65 + 0,7 P/D)} \left( 20 \frac{H}{NR} + 28 M \right) \right)$$

where  $L$  = length, in mm, of the expanded cylindrical section of the blade, at the radius in question,

$T$  = the corresponding maximum blade thickness, in mm,

$P$  = propeller pitch, in metres, at the radius in question. (For controllable pitch propellers  $0,7P_{\text{nominal}}$  is to be used.),

$D$  = diameter of propeller, in metres,

$H$  = shaft power as defined in H 105,



$R$  = propeller rpm,

$M$  = ice torque as defined in 523,

$N$  = number of blades,

$S$  = specified minimum tensile strength, in  $N/mm^2$  ( $kgf/mm^2$ ), of the material.

526 The blade tip thickness,  $t$  at the radius  $D/2$  is to be determined by the following formulae:—

Ice Class IA Super

$$t = (20 + 2 D) \sqrt{\frac{490}{S}} \text{ mm}$$

$$\left( t = (20 + 2 D) \sqrt{\frac{50}{S}} \text{ mm} \right)$$

Ice Classes IA, IB and IC

$$t = (15 + 2 D) \sqrt{\frac{490}{S}} \text{ mm}$$

$$\left( t = (15 + 2 D) \sqrt{\frac{50}{S}} \text{ mm} \right)$$

where  $D$  and  $S$  are as defined in 525.

527 The thickness of other sections is to conform to a smooth curve connecting the section thicknesses as determined by 525 and 526.

528 Where the blade thickness derived by 525 is less than the blade thickness derived by H 403, the latter is to apply.

529 The thickness of blade edges is not to be less than 50 per cent of the derived tip thickness  $t$ , measured at  $1,25 t$  from the edge. For controllable pitch propellers this applies only to the leading edge.

530 The strength of mechanisms in the boss of a controllable pitch propeller is to be 1,5 times that of the blade when a load is applied at the radius  $0,9 D/2$  in the weakest direction of the blade.

#### Screwshafts

531 The diameter,  $d_s$ , at the aft bearing of the screwshaft fitted in conjunction with a solid propeller is not to be less than:—

$$d_s = 1,08 \sqrt[3]{\frac{SLT^2}{f_y}} \text{ mm}$$

where  $S$  = specified minimum tensile strength of the blade material, in  $N/mm^2$  ( $kgf/mm^2$ ),

$L$  and  $T$  = proposed width and thickness respectively of the propeller blade section at  $0,25 D/2$ , in mm,

$f_y$  = specified minimum yield stress of the material of the screwshaft, in  $N/mm^2$  ( $kgf/mm^2$ ).

The diameter,  $d_s$ , at the aft bearing of the screwshaft fitted in conjunction with a controllable pitch propeller is not to be less than:—

$$d_s = 1,15 \sqrt[3]{\frac{SLT^2}{f_y}} \text{ mm}$$

where  $L$  and  $T$  = proposed width and thickness respectively of the propeller blade section at  $0,35 D/2$ , in mm.

532 Where the screwshaft diameter derived by 531 is less than the diameter derived by H 227, the latter is to apply.

The shaft may be tapered at the forward end in accordance with H 227.

#### Intermediate and Thrust Shafts

533 The diameters of intermediate shafts and thrust shafts in external bearings are to comply with H 222 and H 225, respectively, except for Class IA Super ice strengthening where these diameters are to be increased by 10 per cent.

#### Reduction Gearing

534 Where gearing is fitted between the engine and the propeller shafting, the gearing is to be in accordance with H 3 and is to be designed to transmit a torque,  $Y_i$ , determined by the following formula:—

$$Y_i = Y + \frac{M I_h G^2}{I_l + I_h G^2} \text{ kN m (tonne-f m)}$$

$$\text{where } Y = 9,55 \frac{H}{R} \quad \left( 0,716 \frac{H}{R} \right)$$

( $H$  and  $R$  are as defined in 525),

$M$  = ice torque as defined in 523,

$G$  = gear ratio =  $\frac{\text{pinion speed}}{\text{wheel speed}}$ ,

$I_h$  = mass moment of inertia of machinery components rotating at higher speed,

$I_l$  = mass moment of inertia of machinery components rotating at lower speed, including propeller with an addition of 30 per cent for entrained water.

( $I_h$  and  $I_l$  are to be expressed in the same units.)



**Starting Arrangements**

535 In addition to complying with the requirements of H 611 to H 614 where applicable, the capacity of air receivers and/or compressors, or other starting equipment, is to be sufficient for frequent starts within periods lasting several hours.

**Sea Inlet Chests**

536 At least one large cooling water inlet chest is to be connected to the cooling water discharge pipe line by a branch pipe line having the main pipe line diameter, in order to stay free from ice and slush ice. An inlet chest situated well aft in the garboard strake is recommended.

537 In motor ships where clearing steam is not available, fire pumps are to be provided with suctions from the cooling water inlet chest referred to in 536.

**Cross-references**

538 For hull requirements, *see* D 24A.

For ship-side valves, *see* E 267 to E 271.

For materials of propulsion shafting and associated couplings, *see* H 505.

**Section 6**

**GENERAL REQUIREMENTS FOR OIL-ENGINES  
AND STARTING AIR COMPRESSORS**

**Ventilation**

601 Special attention is to be given to the ventilation of the engine room.

**Relief Valves**

602 Cylinder relief valves are to be fitted to engines having cylinders over 230 mm bore. The valves are to be loaded to not more than 40 per cent above the designed maximum pressure and are to discharge where no damage can occur.

In the case of auxiliary engines, consideration will be given to the replacement of the relief valve by an efficient warning device of overpressure in the cylinder.

603 Scavenge spaces in open connection with cylinders are to be provided with explosion relief valves.

**Oil Fuel Systems**

604 On main and auxiliary engines having cylinders of 250 mm bore and above, the high pressure oil fuel injection piping is to be effectively shielded and secured. If flexible hoses are used for shielding purposes, these are to be of an approved type.

The protection is to prevent oil fuel or oil fuel mist from reaching a source of ignition on the engine or its surroundings. Suitable drainage arrangements are to be made for draining any oil fuel leakage and for preventing contamination of the lubricating oil by oil fuel.

605 On engines intended for service in unattended machinery spaces, the high pressure oil fuel injection piping is to be shielded irrespective of the bore of the cylinders.

606 Oil fuel pipe systems in general, tanks and their fittings are to comply with the requirements of D 19 and Chapter E.

**Exhaust Systems**

607 Where the surface temperature of the exhaust pipes and silencer may exceed 220°C, they are to be water cooled or efficiently lagged to minimize the risk of fire and to prevent damage by heat. Where lagging covering the exhaust piping system including flanges is oil-absorbing or may permit penetration of oil, the lagging is to be encased in sheet metal or equivalent. In locations where the Surveyor is satisfied that oil impingement could not occur, the lagging need not be encased.

Where the exhaust is led overboard near the waterline, means are to be provided to prevent water from being syphoned back to the engine. Where the exhaust is cooled by water spray, the exhaust pipes are to be self-draining overboard.

Where the exhausts of two or more engines are led to a common silencer or exhaust gas-heated boiler or economizer an isolating device is to be provided in each exhaust pipe.

For alternatively fired furnaces of boilers using exhaust gases and oil fuel, the exhaust gas inlet pipe is to be provided with an isolating device and interlocking arrangements whereby oil fuel can only be supplied to the burners when the isolating device is closed to the boiler.

In two-stroke main engines fitted with exhaust gas turbo-blowers which operate on the impulse systems, provision is to be made to prevent broken piston rings entering the turbine casing and causing damage to blades and nozzle rings.

**Governors and Overspeed Protective Devices**

608 An efficient governor is to be fitted to each main engine so adjusted that the speed does not exceed that for which the engine is to be classed by more than 15 per cent.

609 Auxiliary engines intended for driving electric generators are to be fitted with governors which, with fixed

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setting, are to control the speed within the following limits:—

10 per cent momentary variation and 5 per cent permanent variation in speed when full load is suddenly taken off or, when after having run on no-load for at least 15 minutes, not less than 70 per cent full load is suddenly applied, followed by the remaining 30 per cent, except in the case of emergency generators which are to be capable of accepting full load under the same test conditions. For a.c. installations, the permanent speed variations of the machines intended for parallel operation are to be equal within a tolerance of  $\pm 0.5$  per cent.

610 Each main engine developing 220 kW (300 shp) or over which can be declutched or which drives a controllable (reversible) pitch propeller, also each auxiliary engine developing 220 kW (300 shp) and over for driving an electric generator, is to be fitted with an approved overspeed protective device.

The overspeed protective device, including its driving mechanism, is to be independent of the governor required by 608 or 609 and is to be so adjusted that the speed does not exceed that for which the engine and its driven machinery are to be classed by more than 20 per cent for main engines and 15 per cent for auxiliary engines.

#### Starting Arrangements

611 Equipment for starting the main and auxiliary engines is to be provided so that the necessary initial charge of starting air or initial electric power can be developed on board ship without external aid. If for this purpose an emergency air compressor or electric generator is required, these units are to be power driven by hand starting oil engine or steam engine, except in the case of small installations where a hand operated compressor of approved capacity may be accepted. Alternatively, other devices of approved type may be accepted as a means of providing the initial start.

612 Two or more starting and manoeuvring air compressors are to be fitted of sufficient total capacity for the requirements of the main engines.

The compressors are to be so designed that the temperature of the air discharged to the starting air receivers will not substantially exceed 93°C in service. A small fusible plug or an alarm device operating at 120°C is to be provided on each compressor to give warning of excessive air temperature. The emergency air compressor is excepted from these requirements.

Each compressor is to be fitted with a safety valve so proportioned and adjusted that the accumulation with the outlet valve closed will not exceed 10 per cent of the maximum working pressure. The casings of the cooling water spaces are to be fitted with a safety valve or bursting disc so that ample relief will be provided in the event of the bursting of an air cooler tube. It is recommended that compressors be cooled by fresh water.

613 Where the main engines are arranged for air starting the total air receiver capacity is to be sufficient to provide, without replenishment, not less than twelve consecutive starts of each main engine if of the reversible type and not less than six consecutive starts if of the non-reversible type. In passenger ships, at least two air receivers are to be provided. For scantlings and fittings of air receivers, see J 2, J 3 and J 6.

614 Where main engines are fitted with electric starters, two batteries are to be fitted. Each battery is to be capable of starting the engines when cold and the combined capacity is to be sufficient without recharging to provide the number of starts of the main engines as required by 613. In other respects batteries are to comply with the requirements of M 13.

#### Starting Air Pipe Systems and Safety Fittings

615 In designing the compressed air installation care is to be taken that the compressor air inlets will be located in an atmosphere reasonably free from oil vapour or alternatively an air duct from outside the machinery space is to be led to the compressors.

The air discharge pipe from the compressors is to be led direct to the starting air receivers. Provision is to be made for intercepting and draining oil and water in the air discharge for which purpose a separator or filter is to be fitted in the discharge pipe between compressors and receivers.

The starting air pipe system from receivers to main and auxiliary engines is to be entirely separate from the compressor discharge pipe system. Stop valves on the receivers are to permit of slow opening to avoid sudden pressure rises in the piping system. Valve chests and fittings in the piping system are to be of ductile material.

Drain valves for removing accumulations of oil and water are to be fitted on compressors, separators, filters and receivers. In the case of any low-level pipe lines, drain valves are to be fitted to suitably located drain pots or separators.

The starting air piping system is to be protected against the effects of explosions by the following arrangements. An isolating non-return valve or equivalent is to be provided at the starting air supply connection to each engine.



In direct reversing engines bursting discs or flame arresters are to be fitted at the starting valves on each cylinder; in non-reversing and auxiliary engines at least one such device is to be fitted at the supply inlet to the starting air manifold on each engine. The fitting of bursting discs or flame arresters may be waived in engines where the cylinder bore does not exceed 230 mm.

Alternative safety arrangements may be submitted for consideration.

#### Crankcase Safety Fittings

**616** Crankcases are to be provided with lightweight spring-loaded valves or other quick-acting and self-closing devices, of an approved type, to relieve the crankcases of pressure in the event of an internal explosion and to prevent any inrush of air thereafter. The valves are to be designed to open at a pressure not greater than 0,02 N/mm<sup>2</sup> (0,2 kgf/cm<sup>2</sup>).

The valve lids are to be made of ductile material capable of withstanding the shock of contact with stoppers at the full open position.

The discharge from the valves is to be shielded by flame guard or flame trap to minimize the possibility of danger and damage arising from the emission of flame.

**617** In engines having cylinders not exceeding 200 mm bore and having a crankcase gross-volume not exceeding 0,6 m<sup>3</sup>, relief valves may be omitted.

In engines having cylinders exceeding 200 mm but not exceeding 250 mm bore, at least two relief valves are to be fitted; each valve is to be located at or near the ends of the crankcase. Where the engine has more than 8 crank throws an additional valve is to be fitted near the centre of the engine.

In engines having cylinders exceeding 250 mm but not exceeding 300 mm bore at least one relief valve is to be fitted in way of each alternate crank throw with a minimum of two valves. For engines having 3, 5, 7, 9, etc., crank throws, the number of relief valves is not to be less than 2, 3, 4, 5, etc., respectively.

In engines having cylinders exceeding 300 mm bore at least one valve is to be fitted in way of each main crank throw.

Additional relief valves are to be fitted for separate spaces on the crankcase, such as gear- or chaincases for camshaft or similar drives, when the gross volume of such spaces exceeds 0,6 m<sup>3</sup>.

**618** The combined free area of the crankcase relief valves fitted on an engine is not to be less than 115 cm<sup>2</sup>/m<sup>3</sup> based on the volume of the crankcase.

The free area of each relief valve is not to be less than 45 cm<sup>2</sup>.

- NOTES. 1. The free area of the relief valve is the minimum flow area at any section through the valve when the valve is fully open.
2. In determining the volume of the crankcase for the purpose of calculating the combined free area of the crankcase relief valves, the volume of the stationary parts within the crankcase may be deducted from the total internal volume of the crankcase.

**619** Alarms giving warning of the overheating of engine running parts, indicators of excessive wear of thrusts and other parts, and detectors of smoke in the crankcase are recommended as means for reducing the explosion hazard. These devices should be arranged to give an indication of failure of the equipment or of the instrument being switched off when the engine is running.

**620** Crankcases and their doors are to be of robust construction and the doors are to be securely fastened so that they will not be readily displaced by an explosion.

**621** Where crankcase vent pipes are fitted, they are to be made as small as practicable to minimize the inrush of air after an explosion. Vents from crankcases of main engines are to be led to a safe position on deck or other approved position.

If provision is made for the extraction of gases from within the crankcase, e.g. for smoke detection purposes, the vacuum within the crankcase is not to exceed 25 mm of water.

Lubricating oil drain pipes from engine sump to drain tank are to be submerged at their outlet ends. Where two or more engines are installed, vent pipes, if fitted, and lubrication oil drain pipes are to be independent to avoid intercommunication between crankcases.

**622** A warning notice is to be fitted in a prominent position, preferably on a crankcase door on each side of the engine, or alternatively at the engine room control station. This warning notice is to specify that whenever overheating is suspected in the crankcase, the crankcase doors or sight holes are not to be opened until a reasonable time has elapsed after stopping the engine, sufficient to permit adequate cooling within the crankcase.

**623** Crankcases of starting air compressors are to be fitted with explosion relief devices as required for auxiliary engines in cases where the crankcase volume is 0,60 m<sup>3</sup> and over.



**Crankcase Lighting**

624 Where interior lighting is provided it is to be flame proof in relation to the interior and details are to be submitted for approval. No wiring is to be fitted inside the crankcase.

**Fire Extinguishing System for Scavenge Manifolds**

625 Scavenge spaces in open connection with cylinders are to be provided with approved fixed or portable fire extinguishing arrangements which are to be independent of the fire extinguishing system of the engine room.

**Hydraulic Tests**

626 In general, items are to be tested by hydraulic pressure as indicated in Table H 6.1. Where design features are such that modifications to the test requirements shown in Table H 6.1 are necessary, alternative proposals for hydraulic tests are to be submitted for special consideration.

**Astern Power**

627 Ships are to have sufficient power for going astern to secure proper control of the ship in all normal circumstances.

TABLE H 6.1

ITEM		TEST PRESSURE
Fuel injection system	Pump body, pressure side	The lesser of 1,5 P or $P + 29,42 \text{ N/mm}^2$ ( $P + 300 \text{ kgf/cm}^2$ )
	Valve	
	Pipe	
Cylinder cover, cooling space Cylinder liner, over the whole length of cooling space Piston crown, cooling space (where piston rod seals cooling space, test after assembly)		0,69 N/mm <sup>2</sup> (7 kgf/cm <sup>2</sup> )
Cylinder jacket, cooling space Exhaust valve, cooling space Turbo blower, cooling space Exhaust pipe, cooling space Coolers, each side Engine driven pumps (oil, water, fuel, bilge)		The greater of 0,39 N/mm <sup>2</sup> (4 kgf/cm <sup>2</sup> ) or 1,5 P
Air compressor, including cylinders, covers, intercoolers and aftercoolers	air side	1,5 P
	water side	The greater of 0,39 N/mm <sup>2</sup> (4 kgf/cm <sup>2</sup> ) or 1,5 P
Scavenge pump cylinder		0,39 N/mm <sup>2</sup> (4 kgt/cm <sup>2</sup> )

- NOTES. 1. P is the maximum working pressure in the item concerned.  
2. Fuel pumps of the jerk or timed pump system are not included.  
3. Turbo blower air coolers need only be tested on the water side.

**Trials**

628 The sea trials are to be of sufficient duration to prove the machinery under power and normal manoeuvring conditions.

It is to be demonstrated that the capacity of starting air receivers is adequate to provide the required number of starts of the main engines.

In the case of passenger ships, the ability of the machinery to reverse the direction of thrust of the propeller in sufficient time, under normal manoeuvring conditions, and so bring the ship to rest from maximum ahead service speed is to be demonstrated at the sea trials.

All trials are to be to the Surveyor's satisfaction.

**Cross-references**

629 The pumping arrangements, including cooling water and lubricating oil systems, are to comply with the requirements of Chapter E.

630 For lists of spare gear to be carried, see Chapter K.

**Section 7****WELDED STRUCTURES FOR OIL ENGINES****General**

701 The requirements of this section are applicable to engines for main propelling purposes.

**Plans**

702 Before construction is commenced plans of bedplates, crankcases, frames and entablatures, including details of the welded joints, materials, electrodes and heat treatment are to be submitted for consideration.

An outline of the welding procedure and fabrication method and sequence is also to be submitted for information.

NOTE. It will not be necessary for plans and particulars to be submitted for each ship provided the basis plans for the engine size and type have previously been approved as meeting the requirements of these Rules. Any alterations to basis design, materials and manufacturing procedure are to be re-submitted for consideration.

**Materials**

703 Plates, sections, forgings and castings are to be of welding quality to an approved specification with a carbon content generally not exceeding 0,23 per cent, and are to be tested in accordance with the requirements of Chapter Q. Steels with higher carbon contents may be approved subject to special tests to prove weldability.



**Construction**

**704** Plates and weld preparations are to be accurately machined or flame-cut to shape. Flame-cut surfaces are to be cleaned by machining or grinding; if the flame-cut surfaces are smooth, wire brushing may be accepted.

Before welding is commenced the component parts of bedplates and framework are to be accurately fitted and aligned. The welding is to be done in positions free from draughts and is to be downhand wherever practicable. Electrodes are to be of an approved type. Preheating is to be adopted when welding heavy plates or sections. The finished welds are to have an even surface and be free from undercutting. Welds attaching bearing housings to the transverse girders are to have a smooth contour and if necessary are to be made smooth by grinding.

**Welded Joints**

**705** Joints in parts of the engine structure which are stressed by the main gas or inertia loads are to be designed as continuous full strength welds and for complete fusion of the joint. They are to be so arranged that, in general, welds do not intersect, and that welding and inspection can be effected without difficulty. Abrupt changes in plate section are to be avoided and where plates of substantially unequal thickness are to be butt welded, the thickness of the heavier plate is to be gradually tapered to that of the thinner plate. Tee joints are to be made with full bevel or equivalent weld preparation to ensure full penetration.

In single plate transverse girders the castings for main bearing housings are to be formed with web extensions which can be butt welded to the flange and vertical web plates of the girder. Stiffeners in the transverse girder are to be attached to the flanges by full penetration welds.

**Heat Treatment**

**706** Bedplates are to be stress relieved except for engine types where the bedplate as a whole is not subjected to direct loading from the cylinder pressure. For the latter types only the transverse girder assemblies need be stress relieved.

Stress relieving is to be done by heating the welded structure uniformly and slowly to a temperature between 580°C to 650°C, holding that temperature for not less than one hour per 25 mm of maximum plate thickness and thereafter allowing the structure to cool slowly in the furnace.

**Inspection**

**707** Welded engine structures are to be examined during fabrication, special attention being given to the fit of component parts of major joints prior to welding. On

completion of welding and stress relieving, all welds are to be examined. Welds in transverse girder assemblies are to be crack detected by an approved method to the satisfaction of the Surveyors. Other joints are to be similarly tested if required by the Surveyors.

The whole of the welding work is to be to the satisfaction of the Surveyors.

**DESIGN RECOMMENDATIONS**

It is recommended that bedplates and major components of engine structures should be made with a minimum number of welded joints.

Double welded butt type joints should be adopted wherever possible in view of their superior fatigue strength.

Girder and frame assemblies should, so far as possible, be made from one plate or slab, shaped as necessary, rather than by welding together a number of small pieces.

Steel castings should be used for parts which would otherwise require complicated weldments.

Care should be taken to avoid stress concentrations such as sharp corners and abrupt changes in section.

**Section 8****GENERAL REQUIREMENTS FOR STEAM TURBINES****Scope**

**801** The following requirements are applicable to steam turbines for main propulsion and for essential auxiliary services where powers exceed 110 kW (150 shp.)

**Plans**

**802** The following plans are to be submitted for consideration, together with particulars of materials and of maximum shaft powers and revolutions per minute (see H 105). The pressures and temperatures applicable at maximum shaft power and under the emergency conditions of 836 are to be stated or indicated on the plans.

1. General arrangement.
2. Sectional assembly.
3. Rotors and couplings.
4. Cylinders.

For the emergency conditions of 837, full particulars are to be submitted of the means proposed for emergency propulsion.



For main turbines plans 1, 2 and 3 are required in all cases and 4 when the cylinders are of welded construction. In general for auxiliary turbines no plans need be submitted.

Where rotors and cylinders are of welded construction plans showing details of the welded joints are also to be submitted for consideration.

#### Materials

**803** Plates, forgings, castings and pipes used in the construction of turbine cylinders, rotors, discs, couplings and other important components are to be of approved composition and be tested in accordance with the relevant requirements of Chapter Q, or of an approved Specification.

**804** In the selection of materials for high temperature applications in advanced turbines consideration is to be given to their creep strength, corrosion resistance and scaling properties at working temperatures to ensure satisfactory performance and long life under service conditions.

**805** Turbine rotors and discs are to be of forged steel. For carbon and carbon-manganese steel forgings the specified range of tensile strength is not to exceed 100 N/mm<sup>2</sup> (10 kgf/mm<sup>2</sup>) within the general limits of 440 and 690 N/mm<sup>2</sup> (45 and 70 kgf/mm<sup>2</sup>). For alloy steel rotor forgings the specified range is not to exceed 150 N/mm<sup>2</sup> (15 kgf/mm<sup>2</sup>) within the general limits of 440 and 930 N/mm<sup>2</sup> (45 and 95 kgf/mm<sup>2</sup>). For discs and other alloy steel forgings the specified range is not to exceed 150 N/mm<sup>2</sup> (15 kgf/mm<sup>2</sup>) within the general limits of 440 and 1130 N/mm<sup>2</sup> (45 and 115 kgf/mm<sup>2</sup>).

When it is proposed to use a steel of higher tensile strength full details are to be submitted for approval. See Q 631 to Q 640.

**806** Turbine cylinder castings are to be of approved material suitable for the working metal temperature. Ordinary cast iron is not to be used for temperatures exceeding 260°C. The castings are to be stress relief heat treated after rough machining, except that this requirement may be waived for small castings at the Surveyors' discretion. The stress relieving temperature is not to exceed the tempering temperature. See Q 504 and Q 507 for steel castings.

#### Stability Testing of Turbine Rotors

**807** All solid forged H.P. turbine rotors intended for main propulsion service where the inlet steam temperature exceeds 400°C are to be subjected to at least one thermal stability test. This requirement is also applicable to rotors fabricated as in 820. The test may be carried out at the Forge or Turbine Builders' Works (a) after heat treatment and rough machining of the forging, or (b) after final

machining, or (c) after final machining and blading of the rotor. The stabilizing test temperature is not to be less than 28°C above the maximum steam temperature to which the rotor will be exposed and not more than the tempering temperature of the rotor material. For details of a recommended test procedure and limits of acceptance, see Q 637(e). Other test procedures may be adopted if approved.

Where main turbine rotors are subjected to thermal stability tests at both Forge and Turbine Builders' Works the foregoing requirements are applicable to both tests. It is not required that auxiliary turbine rotors be tested for thermal stability, but if such tests are carried out, the requirements for main turbine rotors will be generally applicable.

#### Design and Construction

**808** In the design and arrangement of turbine machinery adequate provision is to be made for the relative thermal expansion of the various turbine parts, and special attention is to be given to minimizing casing and rotor distortion under all operating conditions.

**809** Indicators for determining the axial position of rotors relative to their casings and for showing the longitudinal expansion of casings at the sliding feet, if fitted, are to be provided for main turbines. The latter indicators should be fitted at both sides and be readily visible.

**810** Pipes and ducts connected to turbine casings are to be so designed that no excessive thrust loads or moments are applied by them to the turbines. Gratings and any fittings in way of sliding feet or flexible-plate supports are to be so arranged that casing expansion is not restricted. Where main turbine seatings incorporating a tank structure are proposed, consideration is to be given to the temperature variation of the tank in service to ensure that turbine alignment will not be adversely affected.

**811** In arranging the gland-sealing system the pipes are to be made self-draining and every precaution is to be taken against the possibility of condensed steam entering the glands and turbines. The steam supply to the gland-sealing system is to be fitted with an effective drain trap. In the air ejector re-circulating water system the connection to the condenser is to be so located that water cannot impinge on the L.P. rotor or casing.

**812** Turbine bearings are to be so disposed and supported that lubrication is not adversely affected by heat flow from adjacent hot parts of the turbine. Effective means are to be provided for intercepting oil leakage and preventing oil from reaching high temperature glands and casings. Drainage openings from oil baffles are to be amply large.



**813** Discs of built rotors fitted by shrinking are to be secured with keys, dowels or other approved means in main turbines.

**814** Smooth fillets are to be provided at abrupt changes of section of rotors, spindles, discs, blade roots and tenons. The rivet holes in blade shrouds are to be rounded and radiused on top and bottom surfaces and tenons to be radiused at junction with blade tips. Balancing holes in discs are to be well rounded and polished.

**815** Surveyors are to be satisfied as to the workmanship and riveting of blades to shroud bands and that the blade tenons are free from cracks, particularly with high tensile blade material. Test samples are to be sectioned and examined and pull-off tests made if considered necessary by the Surveyors.

**816** All rotors, as finished-bladed and complete with half-coupling, are to be dynamically balanced to the Surveyor's satisfaction in a machine of sensitivity appropriate to the size of rotor.

**817** The turning gear for all propulsion turbines is to be power-driven and, if electric, is to be continuously rated.

#### **Welded Components**

**818** Turbine rotors, cylinders and associated components fabricated by means of welding will be considered for acceptance if constructed by firms whose works are properly equipped to undertake welding of equivalent standards, for rotor and cylinders respectively, to those required by the Rules for Class 1 and Class 2/1 Welded Pressure Vessels. *See J 4.*

**819** Materials used in the construction of turbine rotors, cylinders, diaphragms, condensers, etc., are to be of welding quality.

**820** Where it is proposed to construct rotors from two or more forged components joined by welding, full details of the chemical composition, mechanical properties and heat treatment of the materials, together with electrode particulars, an outline of the welding procedure, method of fabrication and heat treatment are to be submitted for consideration.

**821** Joints in rotors and major joints in cylinders are to be designed as full-strength welds and for complete fusion of the joint.

**822** In the first instance and before work is commenced the Surveyors are to be satisfied that the desired quality of welding is attainable with the proposed welding procedure, and for this purpose test specimens representative of the

welded joints are to be provided for radiographic examination and mechanical tests. For cylinders the mechanical tests of butt joints are to include tensile, bend and nicked bend tests as detailed in J 4. For diaphragms, nozzle plates etc., representative samples are to be sectioned and macro-etched. For rotors the mechanical tests are to include tensile (all weld metal), tensile (joint), bend (transverse), bend (longitudinal) and macro tests as detailed in J 4 or such other tests as may be approved. In subsequent production, check mechanical tests are to be carried out at the Surveyors' discretion if the quality of the welding is found to be unsatisfactory.

**823** Adequate preheating is to be employed for mild steel cylinders and components where the metal thickness exceeds 44 mm and for all low alloy steel cylinders and components and for any part where necessitated by joint restraint.

**824** Stress relief heat treatment is to be applied to all cylinders and associated components on completion of the welding of all joints and attached structures. (*See J 440* for details of stress relief procedure, temperature and duration).

**825** The heat treatment of welded rotors is to be carried out as approved.

**826** Examinations by non-destructive methods are to be made of all cylinders and rotors on completion of heat treatment as follows:—

**CYLINDERS.** Major stressed joints in pressure shells are to be radiographed if practicable; other joints such as nozzle plate and branch pipe connections and diaphragm joints are to be examined by crack detection methods.

**ROTORS.** All joints are to be examined by radiography or other approved methods and by magnetic crack detection methods.

**827** The whole of the welding work is to be to the satisfaction of the Surveyors.

#### **Governors and other Safety Devices**

**828** An overspeed protective device is to be provided for main and auxiliary turbines so as to shut off the steam automatically and prevent the maximum designed speed being exceeded by more than 15 per cent.

**829** Where two or more propulsion turbines are coupled to the same main gear wheel and one overspeed protective device is provided, this is to be fitted to the L.P. ahead turbine. Hand trip gear for shutting off the steam in an emergency is to be provided at the manoeuvring platform.



830 Arrangements are to be made for the steam to the ahead propulsion turbines to be automatically shut off in the event of failure of the lubricating oil pressure; steam is, however, to be made available at the astern turbine for braking purposes in such an emergency. See E 905 for emergency oil supply.

831 Where a turbine installation incorporates a reverse gear, electric transmission or reversible propeller, a speed governor in addition to, or in combination with, the overspeed protective device is to be fitted and is to be capable of controlling the speed of the unloaded turbine without bringing the overspeed protective device into action.

832 Auxiliary turbines intended for driving electric generators are to be fitted with speed governors which, with limited setting, are to control the speed within the following limits:—

10 per cent momentary variation and 5 per cent permanent variation in speed when full load is suddenly taken off or put on, but for any a.c. installation the permanent speed variations of the machines intended for parallel operation are to be equal within a tolerance of  $\pm 0,5$  per cent.

833 Sentinel relief valves are to be provided at the exhaust ends or other approved positions of all main turbines and the valve discharge outlets are to be visible and suitably guarded if necessary. Where a low vacuum cut-out valve is provided the sentinel relief valve at the L.P. exhaust may be omitted.

834 Non-return valves or other means, which will prevent steam and water returning to the turbines, are to be fitted in bleed steam connections.

835 Efficient steam strainers are to be provided close to the inlets to ahead and astern high pressure turbines, or alternatively at the inlets to the manoeuvring valves.

#### Emergency Arrangements

836 In single screw ships fitted with turbines having more than one cylinder, the arrangements are to be such that steam can be led direct to the L.P. turbine and either the H.P. or I.P. turbine can exhaust direct to the condenser. Adequate arrangements and controls are to be provided for these emergency conditions so that the pressure and temperature of the steam will not exceed those which the turbines and condenser can safely withstand.

837 Ships intended for unrestricted service, fitted with steam turbines and having a single main water tube

boiler, are to be provided with means to ensure emergency propulsion in the event of failure of the main boiler.

#### Hydraulic Tests

838 Manoeuvring valves are to be tested to twice the working pressure. The nozzle boxes of impulse turbines are to be tested to 1,5 times the working pressure.

The cylinders of all turbines are to be tested to 1,5 times the working pressure in the casing or to  $0,2 \text{ N/mm}^2$  ( $2 \text{ kgf/cm}^2$ ), whichever is the greater.

For test purposes the cylinders may be subdivided with temporary diaphragms for distribution of test pressures.

Condensers are to be tested in the steam space to  $0,1 \text{ N/mm}^2$  ( $1 \text{ kgf/cm}^2$ ). The water space is to be tested to the maximum pressure which the pump can develop with the discharge valve closed plus  $0,07 \text{ N/mm}^2$  ( $0,7 \text{ kgf/cm}^2$ ), with a minimum test pressure of  $0,2 \text{ N/mm}^2$  ( $2 \text{ kgf/cm}^2$ ). Where the operating conditions are not known, the test pressure is to be not less than  $0,34 \text{ N/mm}^2$  ( $3,5 \text{ kgf/cm}^2$ ). See E 802.

#### Astern Power

839 Sufficient astern power is to be provided to maintain control of the ship in all normal circumstances.

The astern turbines are to be capable of maintaining in free route astern 70 per cent of the ahead revolutions, corresponding to the maximum propulsion shaft horse power for which the machinery is to be classed, for a period of at least 30 minutes without undue heating of the ahead turbines and condensers.

#### Trials

840 The sea trials are to be of sufficient duration to prove the machinery under power and normal manoeuvring conditions.

The ability of the installation to permit astern running at 70 per cent of full power ahead revolutions without adverse effects is to be demonstrated. The astern trial need only be of 15 minutes duration, but may be extended to 30 minutes at the Surveyors' discretion.

Where controllable pitch propellers are fitted the free route astern trial is to be carried out with the propeller blades set in the full astern position.

In the case of passenger ships, the ability of the machinery to reverse the direction of thrust of the propeller in sufficient time, under normal manoeuvring conditions, and so bring the ship to rest from maximum ahead service speed is to be demonstrated at the sea trials.

All trials are to be to the Surveyors' satisfaction.



**Cross-references**

841 Turbines intended for driving electric generators are to comply with the requirements of M 401 and M 402.

842 The pumping arrangements, including cooling water and lubricating oil systems, are to comply with the requirements of Chapter E.

843 For torsional vibrations of shafting, *see* H 243.

844 For lists of spare gear to be carried, *see* Chapter K.

**Section 9****GENERAL REQUIREMENTS FOR GAS TURBINES****Scope**

901 The following requirements are applicable to gas turbines for main propulsion and, where powers exceed 110 kW (150 shp), to those for essential auxiliary services. The requirements do not apply to exhaust gas turbo blowers.

**Plans**

902 The following plans are to be submitted for consideration, together with particulars of materials and the maximum shaft power and revolutions per minute (*see* H 105). The rating as defined in H 105 (a) and (b) is to be taken at standard ambient conditions, thus:—

15°C inlet air temperature, 0.1 N/mm<sup>2</sup> (1 kgf/cm<sup>2</sup>) absolute pressure and, where applicable, a cooling water temperature of 15°C.

Curves should be submitted indicating the variation in performance with ambient conditions and the rating at the temperatures referred to in H 106, should be stated. The pressures and temperatures at maximum shaft power are to be indicated on the plans, where applicable.

1. Sectional assembly.
2. Casings.
3. Combustion chambers and heat exchangers.
4. Rotors, including blades, and couplings.
5. Fuel oil systems, including controls and safety devices.
6. Lubricating oil systems.

Plans 5 and 6 are to be diagrammatic.

For additional machinery plans, where applicable, *see* G 104.

**Materials**

903 In addition to the requirements of H 101, particulars of chemical composition and room temperature mechanical properties of the materials are to be submitted for consideration. Details are also to be submitted, where applicable, of high temperature characteristics of the materials including, at the working temperatures, the associated creep rate and rupture strength for the designed service life, fatigue strength, corrosion resistance and scaling properties. Particulars of heat treatment, including stress relief, where applicable, are to be submitted.

**Design Basis**

904 Calculations of the steady state stresses, including the effect of stress raisers, etc., in the turbine and compressor rotors and blading at the maximum speed and temperature in service are to be submitted for consideration. Such calculations should indicate the designed service life and be accompanied, where possible, by test results substantiating the limiting criteria.

Details of calculations and tests to establish the service life of other stressed parts, including gearing where applicable, bearings, seals, etc., are to be submitted. All calculations and tests should take account of all relevant environmental factors including particular type of service and fuels intended to be used.

**Overhaul Life**

905 The overhaul schedule recommended by the manufacturer is to be submitted for consideration.

**Design and Construction**

906 All parts of turbines, compressors, etc., are to have clearances and fits consistent with adequate provision for the relative thermal expansion of the various components. Special attention is to be given to minimizing casing and rotor distortion under all operating conditions.

907 The air-inlet system is to be designed to minimize the entrance of harmful foreign matter.

908 The arrangement of the turbine exhaust system is to be such as to prevent exhaust gases being drawn into the compressors.

909 Means for preventing the accumulation of salt deposits in the compressors and turbines are to be provided



in installations intended for operation in marine atmospheres.

**910** When it is intended to burn non-distillate fuels forming harmful deposits, adequate provision should be made for periodic removal of the deposits.

**911** Turbine bearings are to be so disposed and supported that lubrication is not adversely affected by heat flow from adjacent hot parts. Effective means are to be provided for intercepting oil leakage and preventing oil from reaching high temperature glands and casings.

**912** Means are to be provided for indicating the temperature of the turbine inlet or exhaust gases and the compressor discharge air.

**913** Consideration should be given to the need for containment, with a view to minimizing and localizing damage, in the event of rotor blade failure.

#### Balancing

**914** All rotors, as finished-bladed and complete with half-coupling, are to be dynamically balanced to the Surveyors' satisfaction in a machine of sensitivity appropriate to the size of rotor.

#### Vibration

**915** For torsional vibrations of shafting, *see* H 243.

**916** For other vibrations, care is to be taken in the design and manufacture of turbine and compressor rotors, rotor discs and rotor blades to ensure freedom from undue vibration within the operating speed range. Calculations of the critical speeds giving full details of the basic assumptions are to be submitted for consideration. Where critical speeds are found by calculation to occur within the operating speed range, vibration tests may be requested in order to verify the calculations.

#### Welded Components

**917** Components fabricated by means of welding will be considered for acceptance if constructed by firms whose works are properly equipped to undertake welding of the standards appropriate to the components according to the relevant paragraphs of J 4 and J 5.

**918** In the first instance and before work is commenced, the Surveyors are to be satisfied that the desired quality of welding is attainable with the proposed welding procedure, and for this purpose test specimens representa-

tive of the welded joints are to be provided for radiographic examination and mechanical tests as required by H 822 for steam turbines.

In subsequent production, check mechanical tests are to be carried out at the Surveyors' discretion if the quality of the welding is found to be unsatisfactory.

**919** Major joints are to be designed as full-strength welds and for complete fusion of the joint.

**920** Stress relief heat treatment is to be applied to all cylinders, rotors and associated components on completion of the welding of all joints and attached structures. *See* J 440.

**921** Before work is commenced, manufacturers are to submit for consideration their proposals for routine examination of joints by non-destructive means.

**922** The whole of the welding work is to be to the satisfaction of the Surveyors.

#### Installation

**923** Pipes and ducting connected to casings are to be so designed that no excessive thrust loads or moments are applied by them to the compressors and turbines, *see also* 906.

Platform gratings and fittings in way of the supports are to be so arranged that casing expansion is not restricted.

Where main turbine seatings incorporating a tank structure are proposed, consideration is to be given to the temperature variation of the tank in service to ensure that turbine alignment will not be adversely affected.

#### Starting

**924** The starting arrangements and starting air pipe systems and safety fittings are to comply with the requirements of H 611 to H 614, where applicable.

**925** Means are to be provided, preferably automatic or interlocked, to clear all parts of the gas turbine of the accumulation of liquid fuel, or for purging gaseous fuel, before ignition commences on starting, or recommences after failure to start.

#### Governors and Other Safety Devices

**926** An overspeed protective device is to be provided for each shaft of main and auxiliary turbines so as to shut off the fuel automatically near the burners, to prevent a dangerous overspeed condition of the shaft, except where it can be established that such a condition cannot arise.



The overspeed device should normally be set to operate when the speed of the line exceeds the rated maximum speed by 10 per cent. For auxiliary turbines driving electric generators this setting may be increased to 15 per cent.

927 Where a main propulsion installation incorporates a reverse gear, electric transmission or controllable (reversible) pitch propeller, a speed governor, independent of the overspeed protective device, is to be fitted and is to be capable of controlling the speed of the unloaded power turbine without bringing the overspeed protective device into action.

928 Where an auxiliary turbine is intended for driving an electric generator, a speed governor, independent of the overspeed protective device, is to be fitted which, with fixed setting, is to control the speed within the following limits:—

10 per cent momentary variation and 5 per cent permanent variation in speed when full load is suddenly taken off or put on, but for any a.c. installation the permanent speed variations of the machines intended for parallel operation are to be equal within a tolerance of  $\pm 0,5$  per cent.

929 Arrangements are to be made in main turbines to shut off the fuel automatically, near the burners, in the event of failure of the lubrication system. See E 905 for emergency oil supply.

Hand trip gear for shutting off the fuel in an emergency is to be provided at the manoeuvring platform.

930 In addition, details of the manufacturer's proposed automatic safety devices to safeguard against hazardous conditions arising in the event of malfunctions in the installation are to be submitted, together with details of fault analysis.

#### Hydraulic Tests

931 All casings are to be tested to a hydraulic pressure equal to 1,5 times the highest pressure in the casing during normal operation, or 1,5 times the pressure during starting, whichever is the higher. For test purposes, if necessary, the casings may be sub-divided with temporary diaphragms for distribution of test pressure.

Where hydraulic tests cannot be carried out, the manufacturers are to submit for approval alternative proposals for determining the soundness of the component.

932 Intercoolers and heat exchangers are to be tested to 1,5 times the maximum working pressure on each side separately.

#### Overspeed Tests

933 Before installation, the gas turbine is to be tested for 5 minutes at 5 per cent above the nominal setting of the overspeed protective device, or 15 per cent above the maximum design speed, whichever is the higher.

Where it is impracticable to overspeed the complete installation, each rotor, completely bladed and with all relevant parts such as half-couplings, shall be overspeed-tested individually at the appropriate speed.

#### Shop Trials

934 The manufacturer's proposals for testing the gas turbine are to be submitted for approval.

#### Alternative Survey Procedure for Line Production

935 Consideration will be given to the adoption of a system of examination involving periodic inspection of the works instead of survey of each individual component. See G 108.

For this purpose, full details of the manufacturer's procedures for quality control and schedule of tests are to be submitted for approval. The Surveyors may require supplementary tests.

#### Astern Power

936 In installations where gas turbines are employed for main propulsion, sufficient astern power is to be provided to maintain control of the ship in all normal circumstances and of maintaining, in free route astern, 70 per cent of the ahead revolutions corresponding to the maximum propulsion shaft power for which the machinery is to be classed.

#### Sea Trials

937 The sea trials are to be of sufficient duration to prove the machinery at the power for which the machinery is to be classed and under normal manoeuvring conditions, also to demonstrate that any vibration which may occur within the operating speed range is acceptable.

The ability of the installation to permit astern running at 70 per cent of the full power ahead revolutions without adverse effects is to be demonstrated. The astern trial need only be of 15 minutes duration, but may be extended to 30 minutes at the Surveyors' discretion.

Where controllable pitch propellers are fitted the free route astern trial is to be carried out with the propeller blades set in the full astern position.

In the case of passenger ships, the ability of the machinery to reverse the direction of thrust of the propeller in sufficient time, under normal manoeuvring conditions, and so bring the ship to rest from maximum ahead service speed is to be demonstrated at the sea trials.



The ability of the means for starting the installation to provide not less than six consecutive starts is to be demonstrated.

All trials are to be to the Surveyors' satisfaction.

**938** The spare gear for gas turbines has not been indicated in view of the variation in turbine design and service conditions. In the circumstances, a list of proposed spare gear is to be submitted for consideration.

#### Cross-references

**939** Gas turbines intended for driving electric generators are also to comply with the requirements of M 401 and M 402.

**940** The piping systems and lubricating oil systems are, in general, to comply with the requirements given in Chapter E, due regard being paid to the particular type of installation.





## Chapter J

# BOILERS AND OTHER PRESSURE VESSELS

### General

The requirements of this Chapter are applicable to fired and unfired pressure vessels of seamless and fusion welded construction, intended for marine services.

The pressure vessels are to be made in accordance with the requirements contained in the following Sections, where applicable:—

- Section 1. General Requirements.
- „ 2. Design.
- „ 3. Construction.
- „ 4. Requirements for Fusion Welding.
- „ 5. Manufacture and Workmanship.
- „ 6. Mountings and Fittings.

Seamless pressure vessels are to be manufactured in accordance with the requirements of Chapter Q 6 or Q 7 where applicable, and tested by hydraulic pressure as for fusion welded pressure vessels (*see* J 445).

NOTE. For riveted pressure vessels, the appropriate requirements of the Society's *Rules for Steel Ships 1975* are to be complied with.

### Section 1

#### GENERAL REQUIREMENTS

##### Design Pressure

101 The design pressure is the maximum permissible working pressure and is not to be less than the highest set pressure of any safety valve. The calculations made to determine the scantlings of the pressure parts are to

be based on the design pressure adjusted, where necessary, to take account of pressure variations corresponding to the most severe operational conditions.

NOTE. It is desirable that there should be a margin between the normal pressure at which the boiler or pressure vessel operates and the lowest pressure at which any safety valve is set to lift, to prevent unnecessary lifting of the safety valve.

##### Metal Temperature

102 The metal temperature  $t$ , used to evaluate the allowable stress  $f$ , is to be taken as the actual metal temperature expected under operating conditions for the pressure part concerned, and is to be stated by the manufacturer when plans of the pressure parts are submitted for consideration. The following values are to be regarded as minimum subject to the overriding provision that  $t$  is not to be less than 250°C and 100°C in the case of fired and unfired pressure vessels respectively.

1. For unfired pressure vessels and for the following parts of fired pressure vessels, such as shells, drums or other pressure components not heated by hot gases and those parts adequately protected by insulation from hot gases,  $t$  is to be taken as the maximum temperature of the internal fluid.
2. For pressure parts heated by hot gases,  $t$  is to be taken as not less than 25°C in excess of the maximum temperature of the internal fluid.

In general, where any parts of boiler drums or headers are not protected by tubes and are exposed to

radiation from the fire, or to the impact of hot gases, they are to be protected by a shield of good refractory materials or by other approved means.

Drums and headers of thickness greater than 30 mm are not to be exposed to combustion gases having an anticipated temperature in excess of 650°C unless they are efficiently cooled by closely arranged tubes accommodated therein.

3. For boiler, superheater, reheater and economizer tubes,  $t$  is to be taken as indicated in J 222.

4. For combustion chambers of the type used in horizontal wet-back boilers,  $t$  is to be taken as not less than 50°C in excess of the maximum temperature of the internal fluid.

5. For furnaces, fireboxes, rear tube plates of dry-back boilers and pressure parts subject to similar rates of heat-transfer,  $t$  is to be taken as not less than 90°C in excess of the maximum temperature of the internal fluid.

#### Materials

103 Materials used in the construction of boilers and other pressure vessels are to be manufactured and tested in accordance with the requirements of Chapter Q.

Rolled steel plates are subject to the limitations of application indicated in Table J 1.1, and for approval purposes the grades of plates specified in Q 3 have been grouped as follows:—

Group 1. Carbon and carbon-manganese steels 360 to 560 N/mm<sup>2</sup> (37 to 57 kgf/mm<sup>2</sup>).

Group 2. Carbon and carbon-manganese steels 510 to 610 N/mm<sup>2</sup> (52 to 62 kgf/mm<sup>2</sup>).

Group 3. Low alloy steels.

As an alternative to the materials stated in Chapter Q consideration will be given to the use of:—

- (a) Materials complying with national or proprietary specifications which give reasonable equivalence to the requirements of Chapter Q, or
- (b) Materials which have higher carbon content or alloy steels not specified in Chapter Q,

provided in both cases details of the chemical composition, heat treatment and mechanical properties are submitted for approval.

Where materials, other than those specified in Chapter Q are proposed, the values of the properties to be used for deriving the allowable stress are to be subject to agreement by the Society.

#### Plans

104 Plans in triplicate of boilers, superheaters and economizers are to be submitted for consideration, as required by G 104. When plans of water tube boilers are submitted for approval particulars of the safety valves and their disposition on boiler and superheater, together with the estimated pressure drop through the superheater, are to be stated. The pressures proposed for the settings of boiler and superheater safety valves are to be indicated on the boiler plan.

In the case of fusion welded pressure vessels plans in triplicate, showing full constructional features of the vessel and dimensional details of the weld grooves for longitudinal and circumferential seams and attachments, together with particulars of the electrodes and of the mechanical properties of the materials are to be submitted before construction is commenced.

TABLE J 1.1

APPLICATION	GROUP OF STEEL	TENSILE STRENGTH LIMITED TO
Welded Pressure Vessels Class 1	1 2 3	360–510 N/mm <sup>2</sup> (37–52 kgf/mm <sup>2</sup> )
Welded Pressure Vessels Class 2/1	1 2	
Welded Pressure Vessels Class 2/2	1	
Welded Pressure Vessels Class 3	1	360–510 N/mm <sup>2</sup> (37–52 kgf/mm <sup>2</sup> )
Boiler furnaces, combustion chambers and flanged plates	1 2	410–610 N/mm <sup>2</sup> (42–62 kgf/mm <sup>2</sup> )



**Allowable Stress**

105 The term allowable stress, designated by  $f$  in the following paragraphs, is the stress to be used in the formulæ for the calculation of scantlings of pressure parts.

The allowable stress  $f$  is the lowest of the following values; the material properties for the appropriate category, grade and tensile range of steel are indicated in Chapter Q.

**Wrought Steel**

$$\text{Fired Pressure Vessels} \quad f = \frac{E_t}{1,6} \quad f = \frac{R_{20}}{2,7} \quad f = \frac{S_R}{1,5}$$

$$\text{Unfired Pressure Vessels} \quad f = \frac{E_t}{1,5} \quad f = \frac{R_{20}}{2,7} \quad f = \frac{S_R}{1,5}$$

where  $E_t$  = specified minimum lower yield stress or 0,2 per cent proof stress at temperature  $t$ ,

$R_{20}$  = specified minimum tensile strength at room temperature,

$S_R$  = average stress to produce rupture in 100 000 hours at temperature  $t$ ,

$t$  = metal temperature (see 102).

The allowable stress for steel castings is to be taken as 80 per cent of the value determined by the method indicated above using the appropriate values for cast steel.

Where steel castings, which have been tested in accordance with Q 5 are also subjected to non-destructive tests, consideration will be given to increasing the allowable stress using a factor up to 90 per cent in lieu of the 80 per cent referred to above. Particulars of the non-destructive test proposals are to be submitted for consideration.

**Joint Factors**

106 Fusion welded pressure parts are to be made in accordance with J 4 and the following joint factors are to be used in the equations in J 2 where applicable.

Class of Welding	Joint Factor
Class 1	1,0
Class 2/1	0,85
Class 2/2	0,75
Class 3	0,60

The longitudinal joints for all classes of vessels are to be butt joints. Circumferential joints for Classes 1, 2/1 and 2/2 vessels are to be butt joints and for Class 3 vessels may be either butt joints or lap joints.

Where a pressure vessel is to be made of alloy steel and where the scantlings have been approved on the basis of the high temperature properties of the material, particulars of the electrodes to be used including typical mechanical properties and chemical composition of the deposited weld metal are to be submitted for approval.

**Classification of Fusion Welded Pressure Vessels**

107 For Rule purposes pressure vessels are graded as follows:—

**CLASS 1**

Pressure parts of boilers and fired pressure vessels intended for design pressures above 0,34 N/mm<sup>2</sup> (3,5 kgf/cm<sup>2</sup>). Pressure parts of steam heated steam generators where the design pressure exceeds 1,13 N/mm<sup>2</sup> (11,5 kgf/cm<sup>2</sup>), or where the design pressure, in N/mm<sup>2</sup> (kgf/cm<sup>2</sup>), multiplied by the internal diameter of the shell, in mm, exceeds 1442 (14 700).

Other pressure vessels where the shell thickness exceeds 38 mm.

**CLASSES 2/1 AND 2/2**

Pressure parts of boilers and fired pressure vessels not included in Class 1.

Pressure parts of steam heated steam generators not included in Class 1.

Other pressure vessels where the design pressure exceeds 1,72 N/mm<sup>2</sup> (17,5 kgf/cm<sup>2</sup>), or the metal temperature exceeds 150°C, or where the design pressure, in N/mm<sup>2</sup> (kgf/cm<sup>2</sup>), multiplied by the actual thickness of the shell, in mm, exceeds 15,69 (160).

Maximum shell thickness 38 mm.

**CLASS 3**

Pressure vessels not included in Classes 1, 2/1 and 2/2.

Maximum shell thickness 16 mm.

Pressure vessels which may be constructed in accordance with Classes 2/1, 2/2 or 3 standards, as indicated above, will, if manufactured in accordance with the requirements of a superior class, be approved with the scantlings appropriate to that class.

In special circumstances relating to service conditions, materials, operating temperature, the carriage of dangerous gases and liquids, etc., it may be necessary to require that certain pressure vessels be manufactured in accordance with the requirements of a superior class.

Heat treatment, non-destructive and routine tests where required, for the four classes of pressure vessel are indicated in Table J 1.2 and details of these requirements are given in J 4.

**Pressure Parts of Irregular Shape**

108 Where pressure parts are of such irregular shape that it is impracticable to design their scantlings by the application of the formulæ in J 2, the suitability of their construction is to be determined by hydraulic proof test of a prototype or by an agreed alternative method.



TABLE J 1.2

CLASS	RADIOGRAPHIC EXAMINATION	HEAT TREATMENT	ROUTINE WELD TESTS	HYDRAULIC TEST
1	required <i>see J 420(a)</i>	<i>see J 439</i>	required	required
2/1	spot required <i>see J 420(b)</i>	<i>see J 439</i>	required	required
2/2	—	<i>see J 439</i>	required	required
3	—	—	—	required

**General**

109 Where working conditions are adverse, special consideration may require to be given to increasing the scantlings derived from the formulæ, e.g. by increasing the corrosion or other allowance at present shown in the formulæ or adopting a design pressure higher than defined in 101, so as to offset the possible reduction of life in service caused by the adverse conditions. In this connection, where necessary, account should also be taken of any excess of loading resulting from:—

- impact loads, including rapidly fluctuating pressures,
- weight of the vessel and normal contents under operating and test conditions,
- superimposed loads such as other pressure vessels, operating equipment, insulation, corrosion-resistant or erosion-resistant linings and piping,
- reactions of supporting lugs, rings, saddles or other types of supports,
- the effect of temperature gradients on maximum stress.

**Design Symbols**

110 The symbols used in the various formulæ in J 2, unless otherwise stated, are as defined below and are applicable to the specific part of the pressure vessel under consideration.

- $T$  = minimum thickness, in mm,  
 $P$  = design pressure (*see* 101), in N/mm<sup>2</sup> (kgf/cm<sup>2</sup>),  
 $D_i$  = inside diameter, in mm,  
 $D_o$  = outside diameter, in mm,  
 $R_i$  = inside radius, in mm,

- $R_o$  = outside radius, in mm,  
 $r_i$  = inside knuckle radius, in mm,  
 $r_o$  = outside knuckle radius, in mm,  
 $p$  = pitch, in mm,  
 $d$  = diameter of hole or opening, in mm,  
 $c$  = corrosion allowance, in mm,  
 $f$  = allowable stress (*see* 105), in N/mm<sup>2</sup> (kgf/cm<sup>2</sup>),  
 $J$  = joint factor applicable to welded seams, or ligament efficiency between tube holes (expressed as a fraction)  
 $t$  = design temperature, in °C.

**Section 2****DESIGN**

## SEAMLESS AND FUSION WELDED CYLINDRICAL SHELLS, DRUMS AND HEADERS SUBJECT TO INTERNAL PRESSURE

**Minimum Thickness**

201 The minimum thickness of a cylindrical shell is to be determined by the following formula:—

$$T = \frac{P R_i}{fJ - 0,5P} + 0,75 \text{ mm}$$

where  $T$ ,  $P$ ,  $R_i$  and  $f$  are as defined in J 110, *see also* J 102 and J 105.

$J$  = efficiency of ligaments between tube holes or other openings in the shell or the joint factor of the longitudinal joints (expressed as a fraction). *See* J 106, 202 to 205, whichever applies. In the case of seamless shells clear of tube holes or other openings  $J = 1,0$ .

The above formula is only applicable where the resulting thickness does not exceed half the internal radius, i.e. where  $R_o$  is not greater than  $1,5 R_i$ .

Irrespective of the thickness determined by the above formula,  $T$  is not to be less than:—

- for unfired pressure vessels 5 mm,
- for drum shell plates of fired pressure vessels, which are unpierced by tube holes, 9,5 mm (*see* Note),
- for tube plates, such thickness as may be necessary to allow a minimum parallel belt width of tube seat of 9,5 mm or such greater width as may be necessary to ensure tube tightness. *See* J 313.

**NOTE.** In special cases where it is proposed to use a shell thickness less than in (b), the proposal will be the subject of special consideration.



### Efficiency of Ligaments between Tube Holes

202 Where tube holes are drilled in a cylindrical shell in a line or lines parallel to its axis the efficiency,  $J$ , of the ligaments is to be determined as follows:—

(a) *Regular drilling.* Where the distance between adjacent tube holes is constant, see Fig. J 2.1,

$$J = \frac{p - d}{p} \quad (1)$$

where  $p$  = pitch of tube holes, in mm,

$d$  = the mean effective diameter of the tube holes, in mm, after allowing for any serrations, counterboring or recessing, or the compensating effect of the tube stub, see 203 and 206.

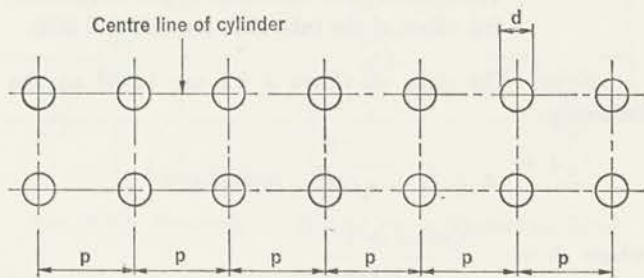


FIG. J 2.1 REGULAR DRILLING

(b) *Irregular drilling.* Where the distance between centres of adjacent tube holes is not constant (see Fig. J 2.2),

$$J = \frac{p_1 + p_2 - 2d}{p_1 + p_2} \quad (2)$$

where  $p_1$  = the shorter of any two adjacent pitches, in mm,

$p_2$  = the longer of any two adjacent pitches, in mm,

$d$  = the mean effective diameter of the tube holes in mm, after allowing for any serrations, counterboring or recessing, or the compensating effect of the tube stub (see 203 and 206).

When applying formula (2) the double pitch ( $p_1 + p_2$ ) chosen is to be that which makes  $J$  a minimum and in no case is  $p_2$  to be taken as greater than twice  $p_1$ .

### Compensating Effect of Tube Stubs

203 Where a drum or header is drilled for tube stubs fitted by strength welding either in line or in staggered formation, the effective diameter of the holes is to be taken

$$\text{as } d_e = d_a - \frac{A}{T} \quad (1)$$

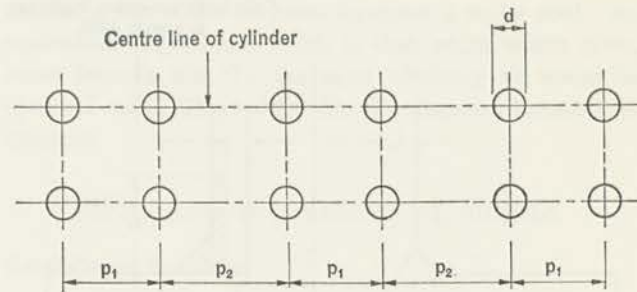


FIG. J 2.2 IRREGULAR DRILLING

where  $d_e$  = the equivalent diameter of the hole, in mm,

$d_a$  = the actual diameter of the hole, in mm,

$T$  = the thickness of the shell, in mm,

$A$  = the compensating area provided by each tube stub and its welding fillets, in mm<sup>2</sup>.

The compensating area,  $A$ , is to be measured in a plane through the axis of the tube stub parallel to the longitudinal axis of the drum or header and is to be calculated as follows (see Figs. J 2.3 and J 2.4):—

(a) The sectional area of the stub, in excess of that required by 222 for the minimum tube thickness, from the interior surface of the shell up to a distance 'b' from the outer surface of the shell (see Notes 1 and 2);

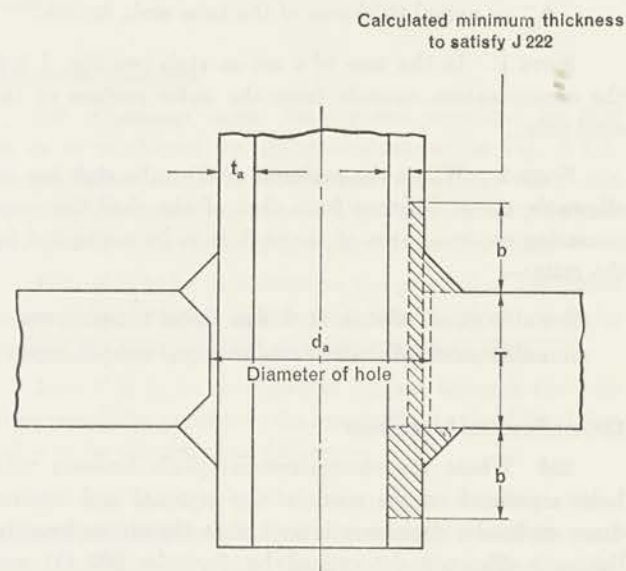


FIG. J 2.3 COMPENSATION OF WELDED TUBE STUBS

Area  $A$  equals twice the area shown cross-hatched

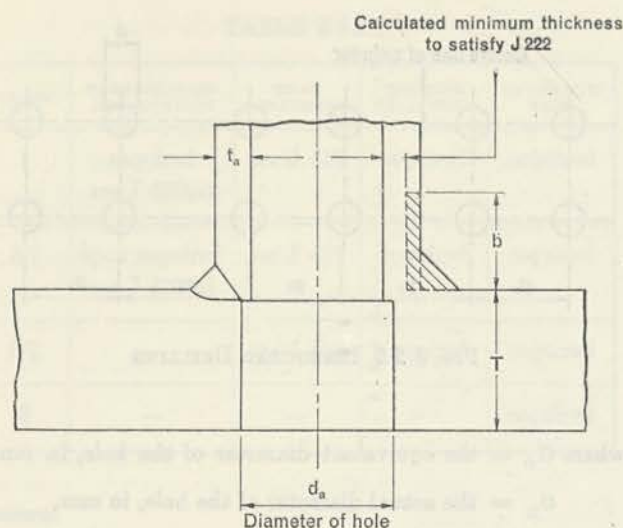


FIG. J 2.4 COMPENSATION OF WELDED TUBE STUBS

Area A equals twice the area shown cross-hatched

(b) plus the sectional area of the stub projecting inside the shell within a distance 'b' from the inner surface of the shell (see Note 2);

(c) plus the sectional area of the welding fillets inside and outside the shell:—

$$\text{where } b = \sqrt{d_a t_a} \quad (2)$$

$t_a$  = actual thickness of the tube stub, in mm.

NOTE 1. In the case of a set-on stub (see Fig. J 2.4) the compensation extends from the outer surface of the shell only.

NOTE 2. Where the material of the tube stub has an allowable stress different from that of the shell the compensating sectional area of the stub is to be multiplied by the ratio:—

$$\frac{\text{allowable stress of stub at design metal temperature}}{\text{allowable stress of shell at design metal temperature}}$$

### Circumferential Ligaments

204 Where the circumferential pitch between tube holes measured on the mean of the external and internal drum or header diameters is such that the circumferential ligament efficiency determined by formulae 202 (1) and 202 (2) is less than one-half of the ligament efficiency on the longitudinal axis, then J in 201 is to be taken as twice the circumferential efficiency.

### Equivalent Longitudinal Ligament Efficiency Drilling on a Diagonal Line

205 (a) Where the tube holes are arranged along a diagonal line with respect to the longitudinal axis as shown in Fig. J 2.5, or are arranged in a regular pattern as shown in Fig. J 2.6; the efficiency, J, to be applied in 201 is to be obtained from the series of curves given in Chart J 2.1 with the ratio  $\frac{b}{a}$  as abscissa and the ratio  $\frac{2a-d}{2a}$  or  $\frac{d}{a}$  as parameter

where a and b as shown in Figs. J 2.5 and J 2.6, are measured in mm on the median line of the plate.

d = mean effective diameter of the tube holes, in mm, after allowing for any serrations, counterboring or recessing, or the compensating effect of the tube stub (see 203 and 206).

NOTE. The data on Chart J 2.1 are based on the following:—

$$J = \frac{2}{A + B + \sqrt{(A - B)^2 + 4C^2}}$$

$$\text{where } A = \frac{\cos^2 \alpha + 1}{2 \left(1 - \frac{d \cos \alpha}{a}\right)}$$

$$B = 0.5 \left(1 - \frac{d \cos \alpha}{a}\right) (\sin^2 \alpha + 1)$$

$$C = \frac{\sin \alpha \cos \alpha}{2 \left(1 - \frac{d \cos \alpha}{a}\right)}$$

$$\cos \alpha = \frac{1}{\sqrt{1 + \frac{b^2}{a^2}}}$$

$$\sin \alpha = \frac{1}{\sqrt{1 + \frac{a^2}{b^2}}}$$

where  $\alpha$  = angle of centreline of cylinder to centreline of diagonal holes.

(b) Where there is regular staggered spacing of tube holes as shown in Fig. J 2.7, the smallest value of the efficiency, J, of all ligaments (longitudinal, circumferential and diagonal) is obtained from Chart J 2.2 with the ratio  $\frac{b}{a}$  as abscissa and the ratio  $\frac{2a-d}{2a}$  or  $\frac{d}{a}$  as parameter

where a and b as shown in Fig. J 2.7 are measured, in mm, on the median line of the plate,



$d$  = mean effective diameter of the tube holes, in mm, after allowing for any serrations, counterboring or recessing, or the compensating effect of the tube stub (*see* 203 and 206).

(c) Where tube holes are irregularly spaced along a drum or header, and do not come in a straight line, the formula 202 (2) is to apply except that an equivalent longitudinal

width of the diagonal ligament is to be used. An equivalent longitudinal width is that width which gives, using formula 202 (1), the same efficiency as would be obtained using Chart J 2.1 for the diagonal ligament in question.

## OPENINGS IN CYLINDRICAL SHELLS

### Unreinforced Openings

206 (a) Openings in a definite pattern such as tube holes may be designed in accordance with the rules for ligaments in 202 to 205 provided that the diameter of the largest hole in the group does not exceed that permitted by (b) below.

(b) The maximum diameter,  $d$ , of any unreinforced opening is to be obtained from the curves in Chart J 2.3 or J 2.4.

In the Charts the value of  $K$  to be used is calculated from the following formula:—

$$K = \frac{P D_o}{1,82 f T}$$

where  $P$ ,  $D_o$  and  $f$  are as defined in J 110, (*see also* J 102 and J 105).

$T$  = actual thickness of shell, in mm.

For elliptical or oval holes,  $d$  refers to the mean of the major and minor axes.

No unreinforced opening is to exceed 200 mm in diameter.

### Reinforced Openings

207 Openings larger than those permitted by 206 are to be reinforced by the method shown in Fig. J 2.8. Compensation shall be considered adequate when the compensating area  $Y$ , *see* Figs. J 2.8(a) and J 2.8(b), is equal to or greater than the area  $X$  requiring compensation.

Area  $X$  is to be calculated as the product of the inside radius of the standpipe and the thickness,  $A$ , which would be required for an equivalent seamless unpierced shell.

Area  $Y$  is to be measured in a plane through the axis of the standpipe parallel to the longitudinal axis of the drum and is to be calculated as follows:—

(a) For that part of the standpipe which projects outside the shell calculate the full sectional area of the stem up to a distance,  $C$ , from the actual outer surface of the shell plate and deduct from it the sectional area which the stem would have if its thickness were as calculated in accordance with 222.

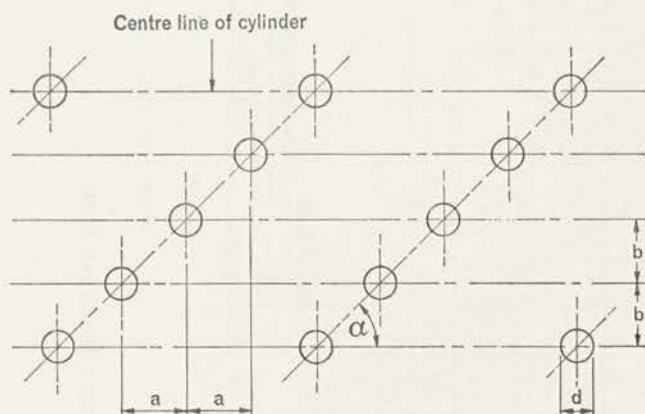


FIG. J 2.5 SPACING OF HOLES ON A DIAGONAL LINE

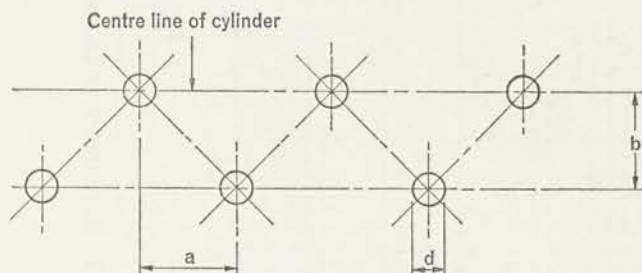


FIG. J 2.6 REGULAR SAW-TOOTH PATTERN OF HOLES

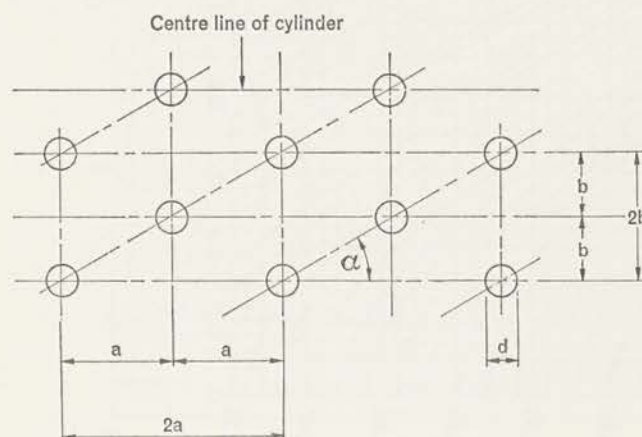


FIG. J 2.7 REGULAR STAGGERING OF HOLES



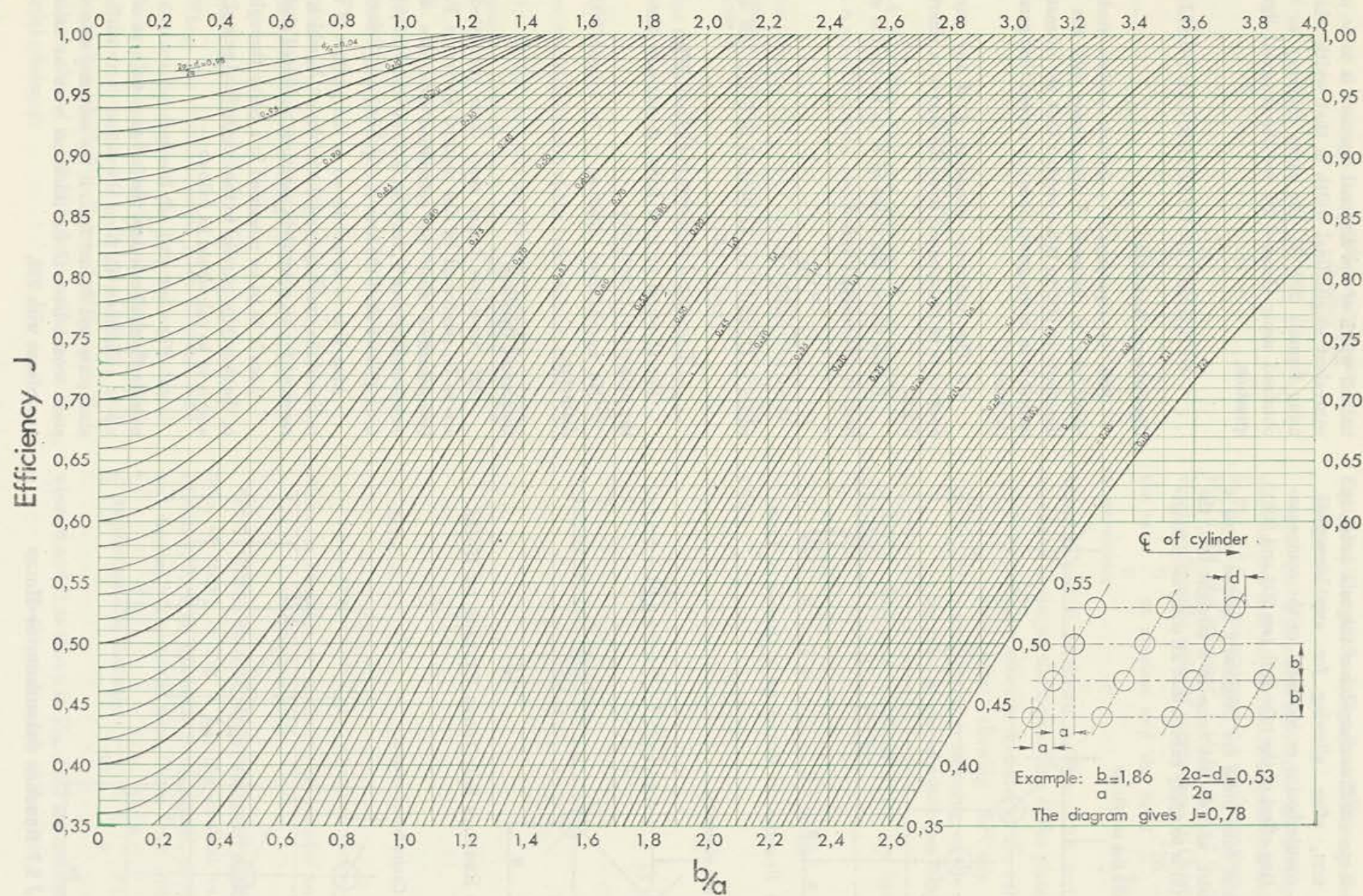


CHART J 2.1 EFFICIENCY OF LIGAMENT ALONG A DIAGONAL LINE







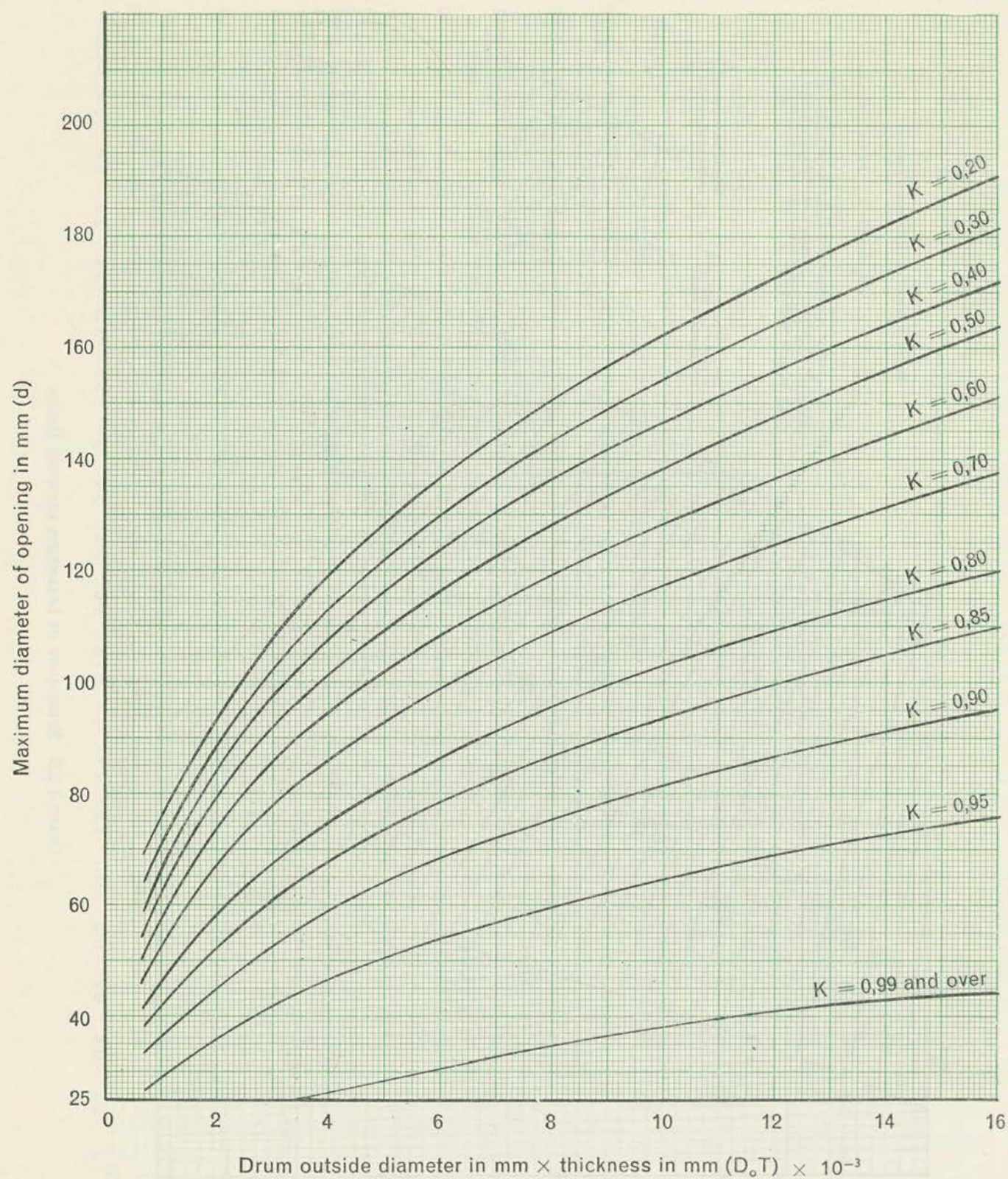
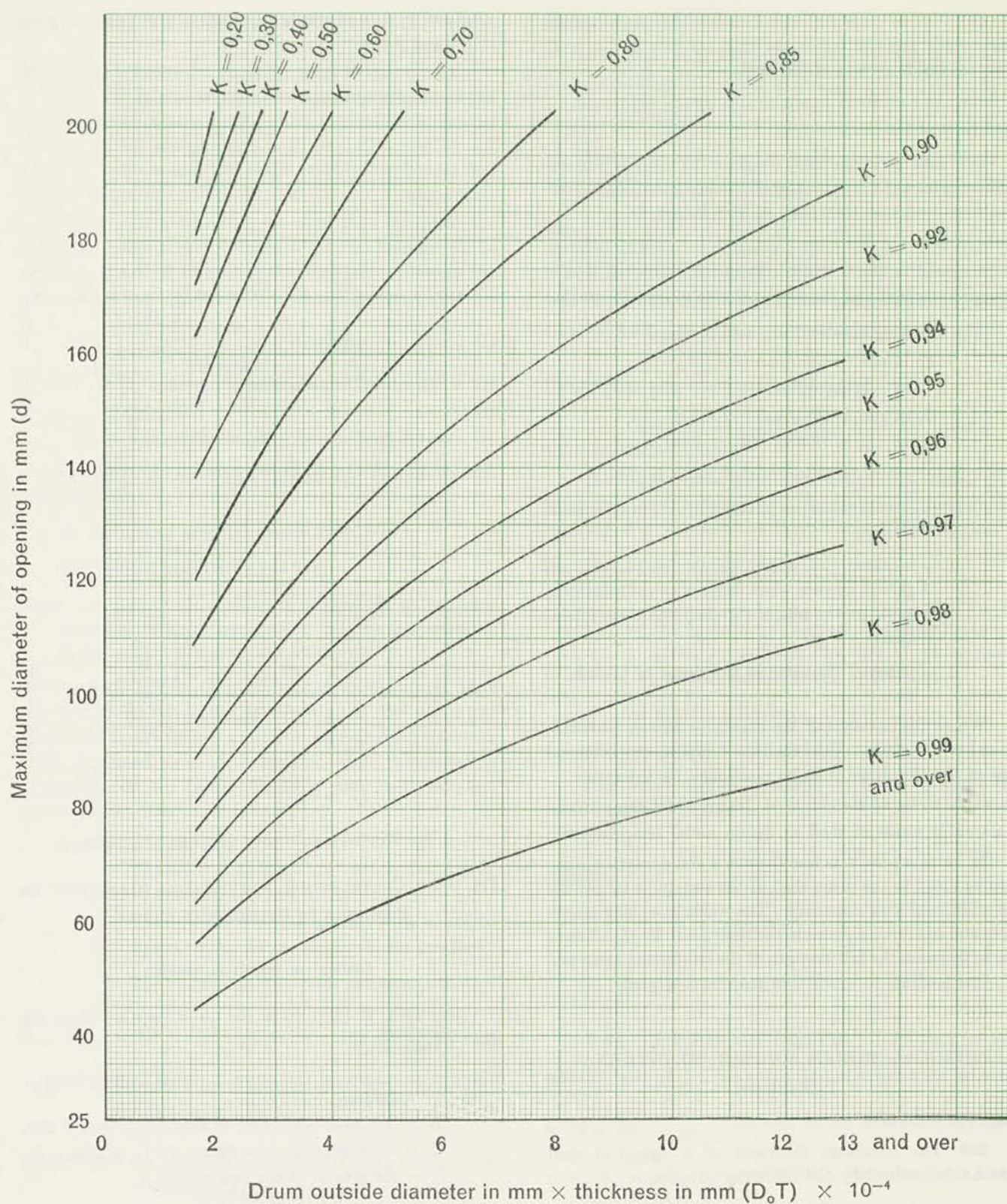


CHART J 2.3 MAXIMUM DIAMETER OF UNREINFORCED OPENINGS







(b) Add to it the full sectional area of that part of the stem which projects inside the shell up to a distance, C, from the inside surface of the shell.

(c) Add to it the sectional area of the fillet welds on both sides of the shell.

(d) Add to it the area obtained by multiplying the difference between the actual shell thickness and the equivalent unpierced shell thickness, A, by a length, D.

(e) If additional reinforcement is required to be fitted as illustrated in Fig. J 2.8(b) add also the sectional area of the reinforcement and the sectional area of its fillet welds.

The following notations are used in Fig. J 2.8:—

C, in mm, is the lesser of  $2,5 T_a$   
or  $2,5 t_a + t_r$

D, in mm, is the greater of  $0,5 d$   
or  $T_a + 75 \text{ mm}$  ( $T_a + 3 \text{ in}$ )

$T_a$  = actual thickness of shell plate, in mm,

$t_a$  = actual thickness of standpipe stem or branch, in mm,

$t_r$  = thickness of added reinforcement, in mm, ( $t_r$  will be zero when there is no compensating plate on the side of the shell under consideration),

d = internal diameter of standpipe or branch, in mm.

Where the material of the standpipe has an allowable stress lower than that of the shell the compensating sectional area of the standpipe is to be multiplied by the ratio:—  
allowable stress of standpipe at design metal temperature  
allowable stress of shell at design metal temperature

In cases where Y is less than X a compensating plate is to be fitted to the drum shell at the standpipe to provide the additional area necessary. The welds attaching standpipes and reinforcing plates to the shell are to be of sufficient size to transmit the full strength of the reinforcing areas and all other loadings to which they may be subjected.

#### SPHERICAL SHELLS SUBJECT TO INTERNAL PRESSURE

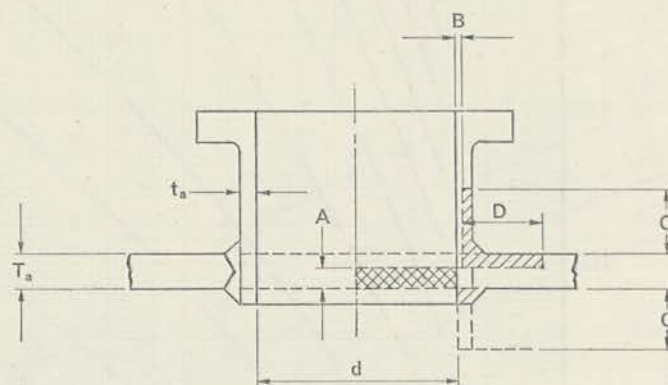
##### Minimum Thickness

208 The minimum thickness of a spherical shell is to be determined by the following formula:—

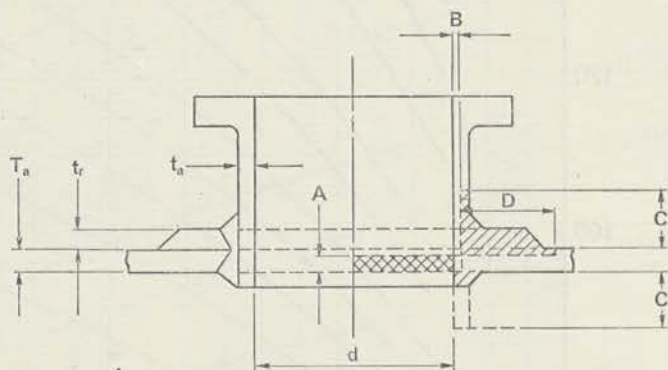
$$T = \frac{PR_i}{2fJ - P} + 0,75 \text{ mm}$$

where T, P,  $R_i$ , f and J are as defined in J 110, see also J 102 and J 105.

In the case of openings in spherical shells, paragraphs 211 to 214 are to be used where applicable.





(a) Welded nozzle



(b) Welded nozzle with compensating plate

FIG. J 2.8 COMPENSATION FOR WELDED STANDPIPES OR BRANCHES IN CYLINDRICAL SHELLS.

#### LIMITS OF REINFORCEMENT

The area Y  is not to be weaker than the area X .

where A = calculated thickness of a shell without joint or opening,

B = thickness calculated in accordance with J 222.

C = the lesser of the two values,  $2,5 T_a$  or  $2,5 t_a + t_r$ ,

D = the greater of the two values:  
 $T_a + 75 \text{ mm}$  or  $0,5 d$ .

NOTE.  $t_r$  shall be equal to zero when there is no compensating plate on the side of the shell under consideration.



## DISHED ENDS SUBJECT TO INTERNAL PRESSURE

## Minimum Thickness

**209** The thickness of torispherical, semi-ellipsoidal and hemispherical unstayed ends, dished from plate, having pressure on the concave side is to be determined by the following formula and the shape of (a) torispherical and (b) semi-ellipsoidal ends is to be within the limits stated below.

Where ends are made from more than one plate the thickness determined by formula (1) will require to be modified by taking account of the joint factor between the plates in the case of Classes 2/1, 2/2 and 3 pressure vessels.

$$T = \frac{P D_o K}{2f} + 0,75 \text{ mm} \quad (1)$$

where  $T$ ,  $P$ ,  $D_o$  and  $f$  are as defined in J 110, see also J 102 and J 105,

$K$  = a shape factor (see 210 and Chart J 2.5).

The minimum thickness of the head,  $T$ , is in no case to be less than:—

- (i) for unfired pressure vessels 5 mm.
- (ii) for fired pressure vessels 9,5 mm.

**NOTE.** In special cases where it is proposed to use ends having a thickness less than in (ii), the proposal will be the subject of special consideration.

For ends which are butt welded to the drum shell (see J 106) the thickness of the edge of the flange for connection to the shell is not to be less than the thickness of an unpierced seamless or welded shell, whichever is applicable, of the same diameter and material and determined by 201.

(a) *Torispherical ends*

The internal radius,  $R_i$ , of dishing is not to be greater than  $D_o$ .

The internal knuckle radius,  $r_i$ , is not to be less than  $0,1D_o$  or  $3T$ , whichever is the greater.

The external height,  $H$ , is not to be less than  $0,18D_o$ , and is to be determined as follows:—

$$H = R_o - \sqrt{(R_o - 0,5 D_o)(R_o + 0,5 D_o - 2 r_o)} \quad (2)$$

(b) *Semi-Ellipsoidal ends*

The external height,  $H$ , is not to be less than  $0,2 D_o$

where  $D_o$  = the external diameter of the parallel portion of the end, in mm,

In both cases  $H$  is to be measured from the commencement of curvature (see Fig. J 2.9).

## Shape Factors for Dished Ends

**210** The shape factor,  $K$ , to be used in 209, formula (1), is obtained from the curves in Chart J 2.5 and depends on the ratio of height to diameter  $\frac{H}{D_o}$ .

The lowest curve in the series provides the factor  $K$  for plain (i.e. unpierced) ends. Where the value  $\frac{H}{D_o}$  is lower than 0,25 the value of  $K$  depends on the ratio of thickness to diameter  $\frac{T}{D_o}$  as well as on the ratio  $\frac{H}{D_o}$  and a trial calculation may be necessary to arrive at the correct value of  $K$ .

## Dished Ends with Unreinforced Openings

**211** Openings in dished ends may be circular or approximately elliptical.

The upper curves on Chart J 2.5 provide values of  $K$  to be used in 209, formula (1), for ends with unreinforced openings (e.g. manholes or tube holes). The selection of

the correct curve depends on the value  $\frac{d}{\sqrt{D_o T}}$

where  $d$  = the diameter of the largest opening in the end plate, in mm, (in the case of an elliptical opening, the larger axis of the ellipse),

$T$  = minimum thickness, after dishing, in mm,

$D_o$  = outside diameter of dished end, in mm.

Trial calculation is necessary in order to select the correct curve.

The following requirements must in any case be satisfied:—

$\frac{T}{D_o}$  is not to exceed 0,1

$\frac{d}{D_o}$  is not to exceed 0,7.

**NOTE.** It will be seen from Chart J 2.5 that for any selected ratio of  $\frac{H}{D_o}$ , the curve for unpierced ends indicates a value for  $\frac{d}{\sqrt{D_o T}}$  as well as for  $K$ . Holes giving a value of  $\frac{d}{\sqrt{D_o T}}$  not greater than the value so obtained may thus be pierced through an end designed as unpierced without any increase in thickness.



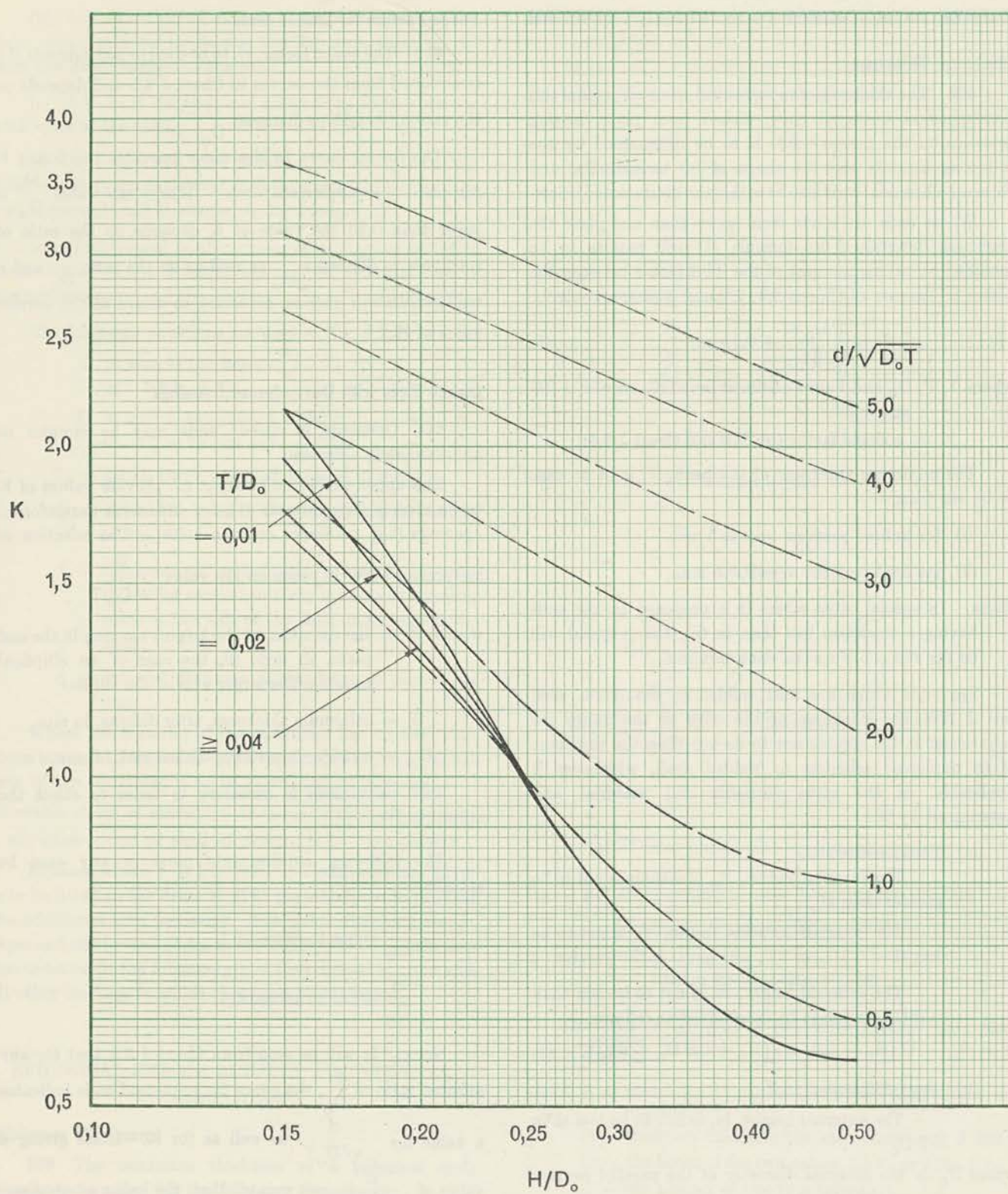


CHART J 2.5 SHAPE FACTOR



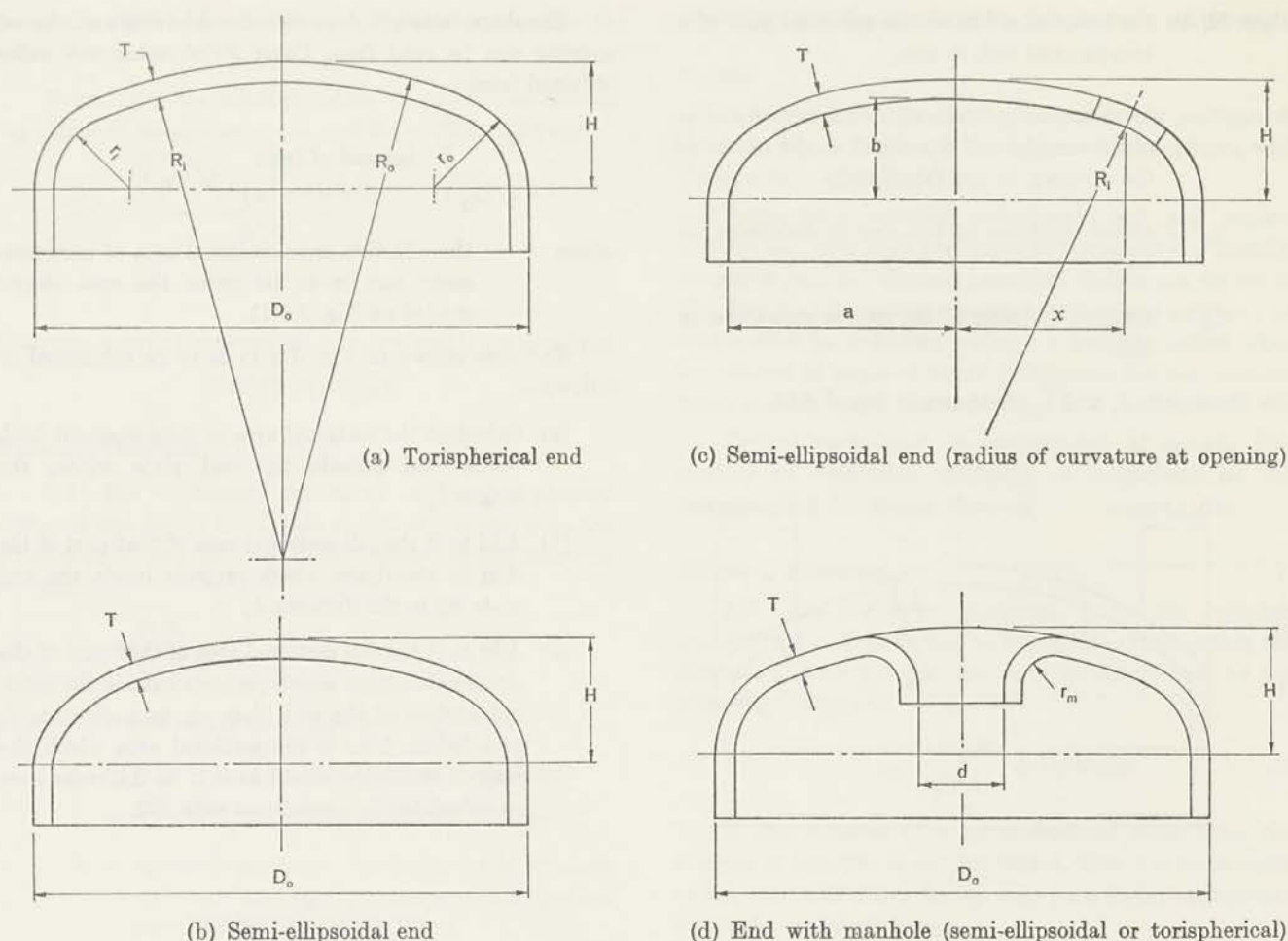


FIG. J 2.9 TYPICAL DISHED ENDS

**Flanged Openings in Dished Ends**

212 The requirements in 211 apply equally to flanged openings and to unflanged openings cut in the plate of an end. No reduction may be made in end plate thickness on account of flanging.

Where openings are flanged the radius,  $r_m$ , of the flanging is not to be less than 25 mm, see Fig. J 2.9(d). The thickness of the flanged portion may be less than the calculated thickness.

**Location of Unreinforced and Flanged Openings in Dished Ends**

213 Unreinforced and flanged openings in dished ends are to be so arranged that the distance from the edge of the hole to the outside edge of the plate and the distance between openings are not less than those shown in Fig. J 2.10. In Fig. J 2.10,  $d_2$  is equal to the diameter of the smaller hole.

**Dished Ends with Reinforced Openings**

214 Where it is desired to use a large opening on a dished end of less thickness than would be required by the application of 211 reinforcement of the end is to be provided.

Reinforcement may consist of a ring or standpipe welded into the hole, or of reinforcing plates welded to the outside and/or inside of the end in the vicinity of the hole, or a combination of both methods, see Fig. J 2.11. Forged reinforcements may be used.

Reinforcing material within the following limits may be taken as effective reinforcement.

- (a) The effective width  $l_1$  of reinforcement is not to exceed  $\sqrt{2 R_i T}$  or  $0.5 d_o$  whichever is the lesser.
- (b) The effective length  $l_2$  of a reinforcing ring is not to exceed  $\sqrt{d_o t_a}$

where  $R_i$  = the internal radius of the spherical part of a torispherical end, in mm,

or for a semi-elliptical end, the internal radius of the meridian of the ellipse at the centre of the opening, in mm (see Note),

$t_a$  = actual thickness of the ring or standpipe, in mm,

$d_o$  = external diameter of the ring or standpipe, in mm.

The dimensions  $l_1$  and  $l_2$  are shown in Fig. J 2.11.

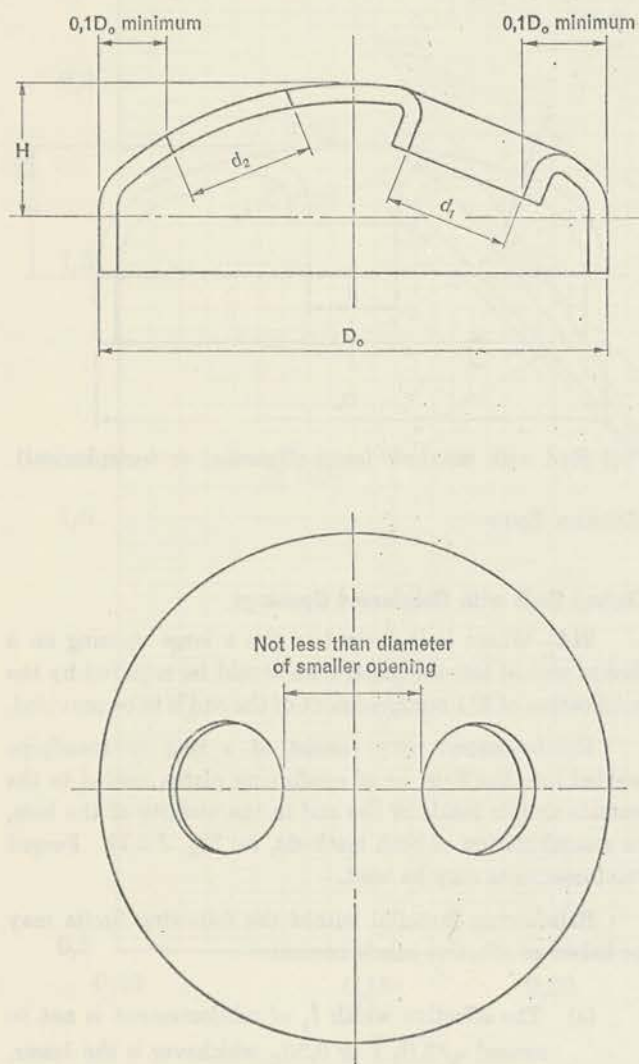


FIG. J 2.10 OPENINGS IN DISHED ENDS

The shape factor,  $K$ , for a dished end having a reinforced opening can be read from Chart J 2.5 using the value obtained from:—

$$d_o - \frac{A}{\sqrt{D_o T}} \text{ instead of from } \frac{d}{\sqrt{D_o T}}$$

where  $A$  = the effective cross-sectional area of reinforcement and is to be twice the area shown shaded on Fig. J 2.11.

The area shown in Fig. J 2.11 is to be calculated as follows:—

- Calculate the sectional area of reinforcement both inside and outside the end plate within the length  $l_1$ .
- Add to it the full sectional area of that part of the ring or standpipe which projects inside the end plate up to the distance  $l_2$ .
- Add to it the full sectional area of that part of the ring or standpipe which projects outside the internal surface of the end plate up to a distance  $l_2$  and deduct from it the sectional area which the ring or standpipe would have if its thickness were as calculated in accordance with 222.

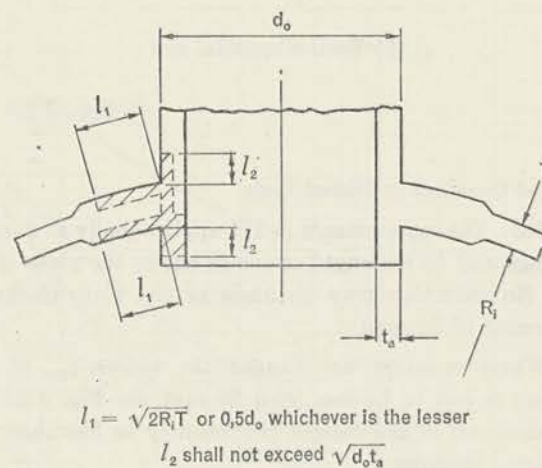


FIG. J 2.11 LIMITS OF REINFORCEMENT

If the material of the ring or the reinforcing plates has an allowable stress lower than that of the end plate then the effective cross-section,  $A$ , must be reduced below that calculated in proportion to the difference in the allowable stresses for the materials.



As in 211 trial calculation is necessary in order to select the correct curve.

NOTE. For the internal radius,  $R_i$ , of the meridian of the ellipse at the centre of the opening (see Fig. J 2.9(c)):

$$R_i = \frac{[a^4 - x^2(a^2 - b^2)]^{\frac{3}{2}}}{a^4 b}$$

### DISHED ENDS RESTRICTED TO CLASS 3 PRESSURE VESSELS ONLY

#### Minimum Thickness

215 The minimum thickness of a torispherical unstayed end dished from plate and having pressure on the concave or convex side is to be determined by the following formula:—

$$T = \frac{P R_i}{C S}$$

where  $T$ ,  $P$  and  $R_i$  are as defined in J 110,

$C = 0,257$  (25,7) for ends concave to pressure,

$C = 0,165$  (16,5) for ends convex to pressure,

$S$  = specified minimum tensile strength of plate, in  $N/mm^2$  ( $kgf/mm^2$ ), which should be not less than  $410 N/mm^2$  ( $42 kgf/mm^2$ ).

The inside radius of curvature,  $R_i$ , of the end plate is not to be greater than the external diameter of the cylinder to which it is attached.

The inside knuckle radius,  $r_i$ , of the arc joining the cylindrical flange to the spherical surface of the end is not to be less than four times the thickness of the end plate and in no case less than 65 mm.

Ends convex to pressure are not to be used for vessels exceeding 610 mm internal diameter.

Where the end is provided with a flanged manhole the thickness of the end, in mm, determined by the foregoing formula is to be increased by 3 mm and the total depth,  $H$ , of the manhole flange, measured from the outer surface of the plate on the minor axis is not to be less than

$$H = \sqrt{T_1 W}$$

where  $H$  = depth of flange, in mm,

$T_1$  = required thickness of the plate, in mm,

$W$  = minor axis of the manhole, in mm.

### CONICAL ENDS SUBJECT TO INTERNAL PRESSURE

#### General

216 Conical ends and conical reducing sections as shown in Fig. J 2.12 are to be designed in accordance with the equations given in 217.

Connections between cylindrical shell and conical sections and ends shall preferably be by means of a knuckle transition radius. Typical permitted details are shown in Fig. J 2.12. Alternatively, conical sections and ends may be butt-welded to cylinders without a knuckle radius when the change in angle of slope  $\psi$  between the two sections under consideration does not exceed  $30^\circ$ .

Conical ends may be constructed of several ring sections of decreasing thickness as determined by the corresponding decreasing diameter.

#### Minimum Thickness

217 The minimum thickness,  $T$ , of the cylinder, knuckle and conical section at the junction and within the distance  $L$  from the junction is to be determined by the following formula:—

$$T = \frac{P D_o K}{2 f J} + 0,75 \text{ mm} \quad (1)$$

If the distance of a circumferential seam from the knuckle or junction is not less than  $L$  then  $J$  is to be taken as 1,0, otherwise  $J$  is to be the weld joint factor appropriate to the circumferential seam.

In the event of the thickness determined by formula (2) being greater than that obtained using formula (1), the greater of the two thicknesses is to apply.

The minimum thickness,  $T$ , of those parts of conical sections not less than a distance  $L$  away from the junction with a cylinder or other conical section is to be determined by the following formula:—

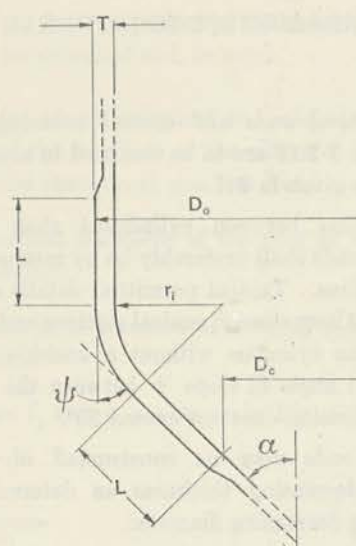
$$T = \frac{P D_c}{(2 f J - P)} \left( \frac{1}{\cos \alpha} \right) + 0,75 \text{ mm} \quad (2)$$

where  $T$ ,  $P$ ,  $f$  and  $J$  are as defined in J 110, see also J 102 and J 105,

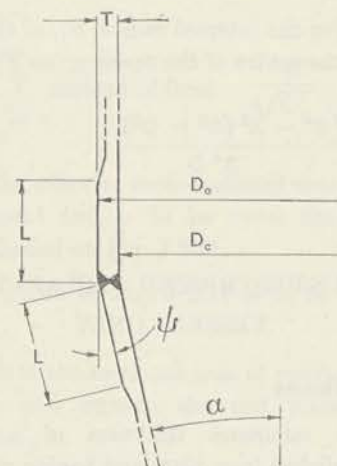
$D_c$  = inside diameter, in mm, of conical section or end at the position under consideration (see Fig. J 2.12),

$D_o$  = outside diameter, in mm, of the conical section or end (see Fig. J 2.12),

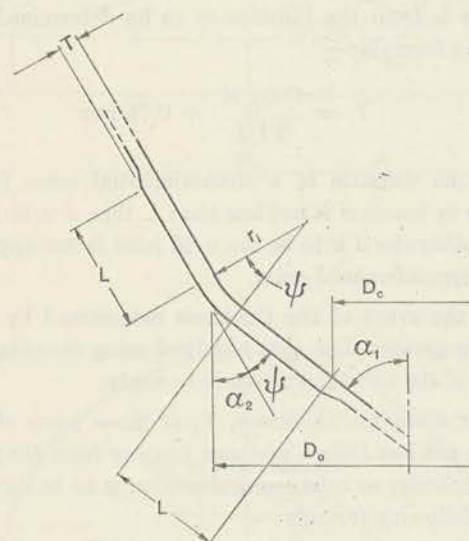
$r_i$  = inside radius of transition knuckle, in mm, which is to be taken as  $0,01 D_c$  in the case of conical sections without knuckle transition,



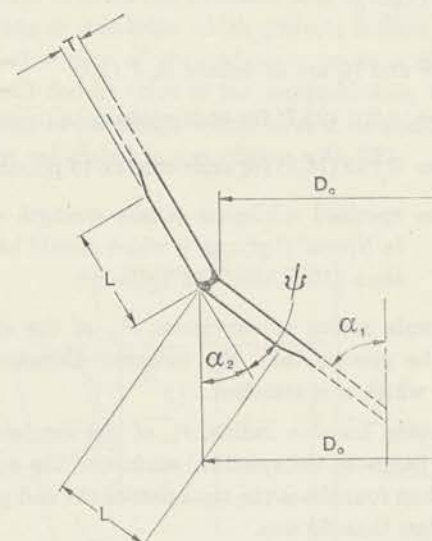
(a) Cone/cylinder with knuckle



(b) Cone/cylinder without knuckle



(c) Cone/cone with knuckle



(d) Cone/cone without knuckle

FIG. J 2.12

$\alpha, \alpha_1, \alpha_2$  = angle of slope of conical section (at the point under consideration) to the vessel axis (see Fig. J 2.12),

$\psi$  = difference between angle of slope of two adjoining conical sections (see Fig. J 2.12),

$K$  = a factor, taking into account the stress in the knuckle (see Table J 2.1),

$L$  = distance, in mm, from knuckle or junction within which meridional stresses determine the required thickness (see Fig. J 2.12),

$$= 0,5 \sqrt{\frac{D_o T}{\cos \psi}}$$

The thickness of conical sections having an angle of inclination to the vessel axis of more than  $75^\circ$  is to be determined as for a flat plate.

Fig. J 2.12



TABLE J 2.1 VALUES OF K AS A FUNCTION OF  $\psi$  AND  $r_i/D_o$ 

$\psi$	VALUES OF K FOR $r_i/D_o$ RATIOS OF											
	0,01	0,02	0,03	0,04	0,06	0,08	0,10	0,15	0,20	0,30	0,40	0,50
10°	0,70	0,65	0,60	0,60	0,55	0,55	0,55	0,55	0,55	0,55	0,55	0,55
20°	1,00	0,90	0,85	0,80	0,70	0,65	0,60	0,55	0,55	0,55	0,55	0,55
30°	1,35	1,20	1,10	1,00	0,90	0,85	0,80	0,70	0,65	0,55	0,55	0,55
45°	2,05	1,85	1,65	1,50	1,30	1,20	1,10	0,95	0,90	0,70	0,55	0,55
60°	3,20	2,85	2,55	2,35	2,00	1,75	1,60	1,40	1,25	1,00	0,70	0,55
75°	6,80	5,85	5,35	4,75	3,85	3,50	3,15	2,70	2,40	1,55	1,00	0,55

## STANDPIPES AND BRANCHES

## Minimum Thickness

218 The minimum wall thickness of standpipes and branches is not to be less than that determined by 222 making such additions as may be necessary on account of bending, static loads and vibration.

The wall thickness, however, is not to be less than:—

$$T = 0,04 D_o + 2,5 \text{ mm}$$

where  $T$  and  $D_o$  are as defined in J 110.

In no case need the wall thickness exceed that of the shell.

Where a standpipe or branch is connected by screwing, the thickness is to be measured at the root of the thread.

For boiler, superheater or economizer tubes the minimum thickness of the drum or header connection or tube stub is to be calculated as part of the tube in accordance with 222.

## HEADERS

## Rectangular Section Headers

219 The thickness of flat surfaces of rectangular solid forged headers (exclusive of staggered, sinuous or corrugated headers) is not to be less than:—

$$T + 0,75 \text{ mm} \quad (1)$$

where  $T$  = the greatest basic thickness, in mm, derived as follows by the use of Chart J 2.6 which gives ratios of thickness to effective width of header.

Two investigations are necessary to deal with:—

- the stress at the corner of the header,
- the stress in the ligaments between tube holes or other openings piercing the flat face of the header.

The efficiency,  $J$ , of the ligaments is calculated as in 202 to 205.

Where a header is drilled for several rows of tube holes the lowest calculated efficiency is to be used.

Chart J 2.6 shows values of  $\frac{T}{B}$  corresponding to values

of a term,  $K$ , for parameters of  $\frac{A}{B}$

where  $A$  = the distance, in mm, between the centre line of the openings and the limit of the effective width,  $B$ , of the header (where there is more than one row of holes,  $A$  is the distance to the row showing the lowest efficiency),

$B$  = the effective width, in mm, of the pierced surface under consideration measured between the supporting sides of the headers, minus one corner radius. This effective width is not to be taken as less than 0,9 of the full distance between the sides.

The corner radius is not to be less than 6,5 mm (see illustration of  $A$  and  $B$  on Chart J 2.6).

$$K = \frac{f J}{P}$$

where  $P$  and  $f$  are as defined in J 110, see also J 102 and J 105,

$J$  = the lowest ligament efficiency expressed as a fraction.

It will be seen that in case (i)  $\frac{A}{B} = 0$  and  $J = 1$ .

Where the header surfaces are machined locally at hand holes the total thickness may be reduced by a maximum of 4 mm.

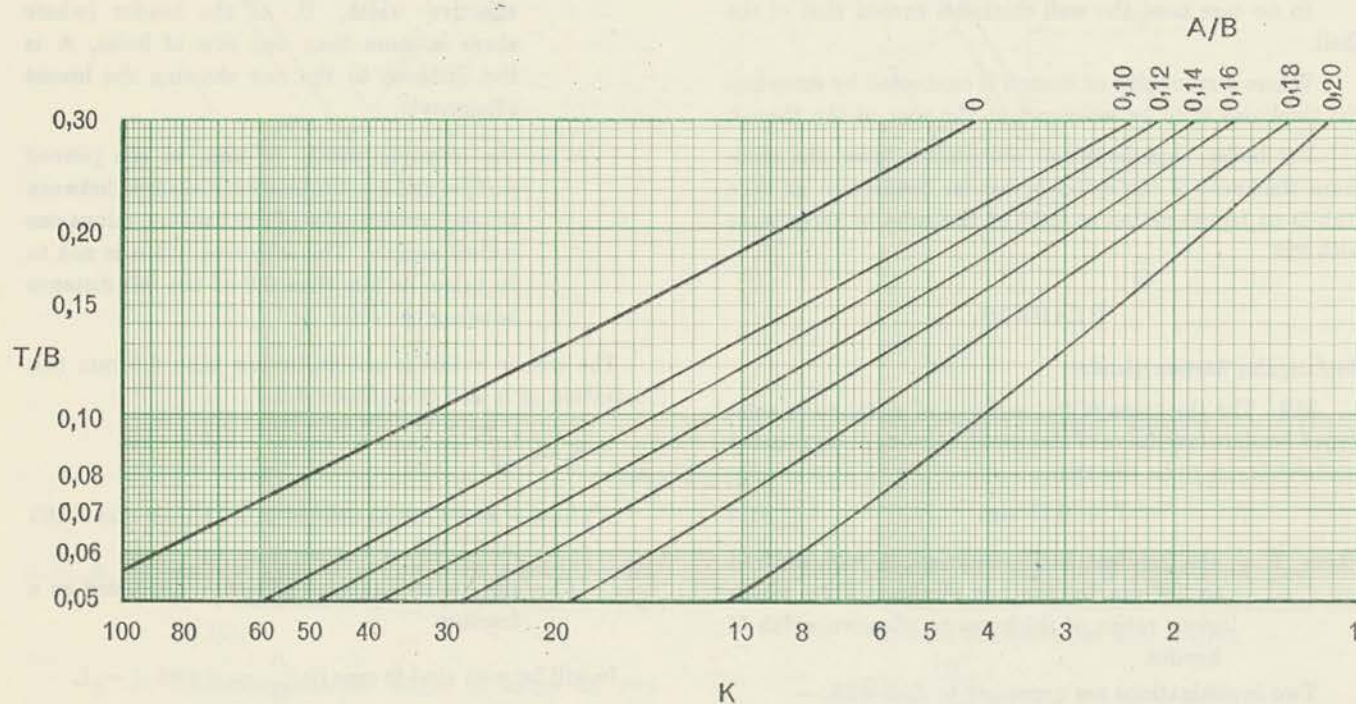
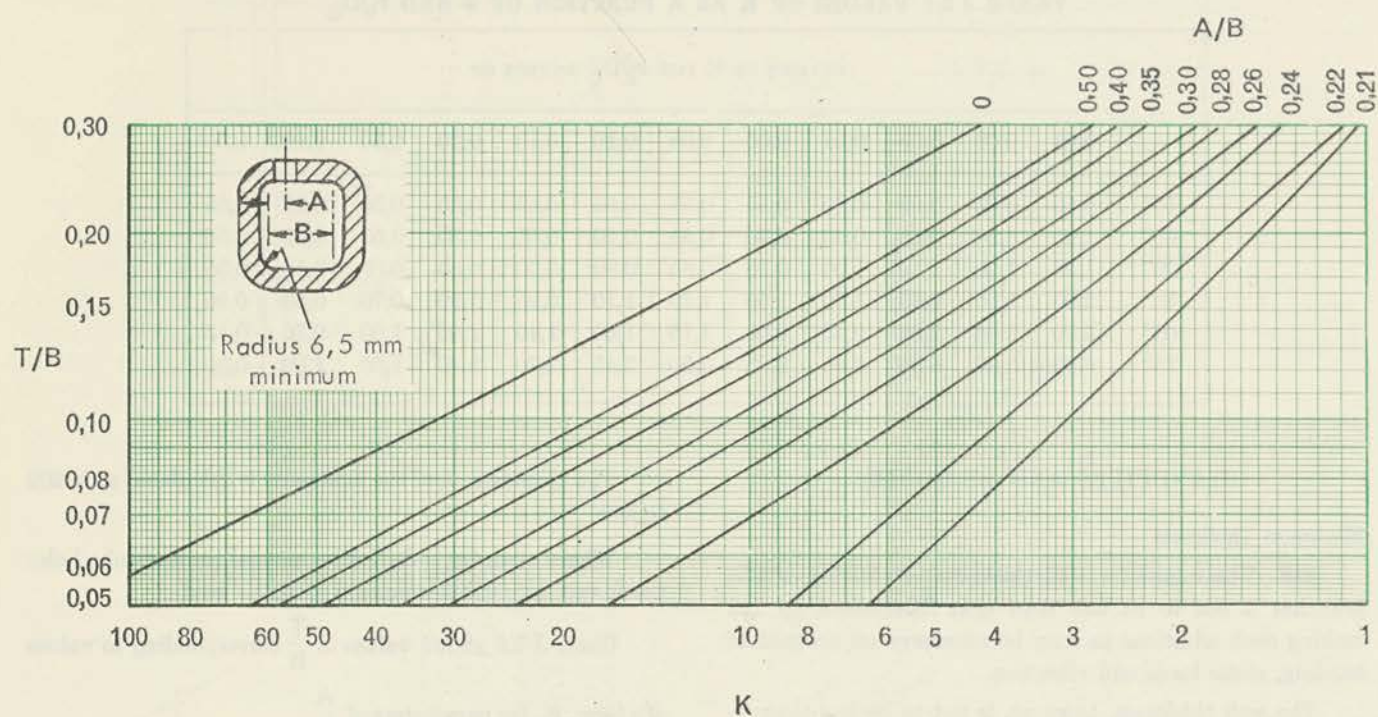


CHART J 2.6 RECTANGULAR SECTION HEADERS



Except for small areas not exceeding 3,25 cm<sup>2</sup> where a reduction of designed thickness up to 50 per cent may be permitted, the thickness derived from use of Chart J 2.6 is to be the minimum. Such minimum is in no case to be less than 7,5 mm or, where tube holes are drilled, to be less than

$$T = 0,5 \sqrt{d} + 6,35 \text{ mm} \quad (2)$$

where  $d$  = the diameter of the tube hole, in mm.

### Staggered, Sinuous or Corrugated Headers

220 The scantlings of staggered, sinuous or corrugated headers shall be the subject of special consideration.

Where sufficient experience of previous satisfactory service of similar headers cannot be shown, the suitability of headers is to be proved in accordance with the provisions of J 108.

### Header Ends

221 The shape and thickness of ends forged integrally with the bodies of headers are to be the subject of special consideration.

Where sufficient experience of previous satisfactory service of headers with similar ends cannot be shown the suitability of a proposed form of end is to be proved in accordance with the provisions of J 108.

Ends attached by welding are to be designed as follows:—

(a) *Dished ends.* These are to be in accordance with 209.

(b) *Flat ends.* The minimum thickness of flat end plates is to be determined by the following formula:—

$$T = d_i \sqrt{\frac{P C}{f}}$$

where  $P$  and  $f$  are as defined in J 110, see also J 102 and J 105,

$T$  = minimum thickness of end plate, in mm,

$d_i$  = internal diameter of circular header or least width between walls of rectangular header, in mm,

$C$  = a constant depending on method of end attachment, see Fig. J 2.13.

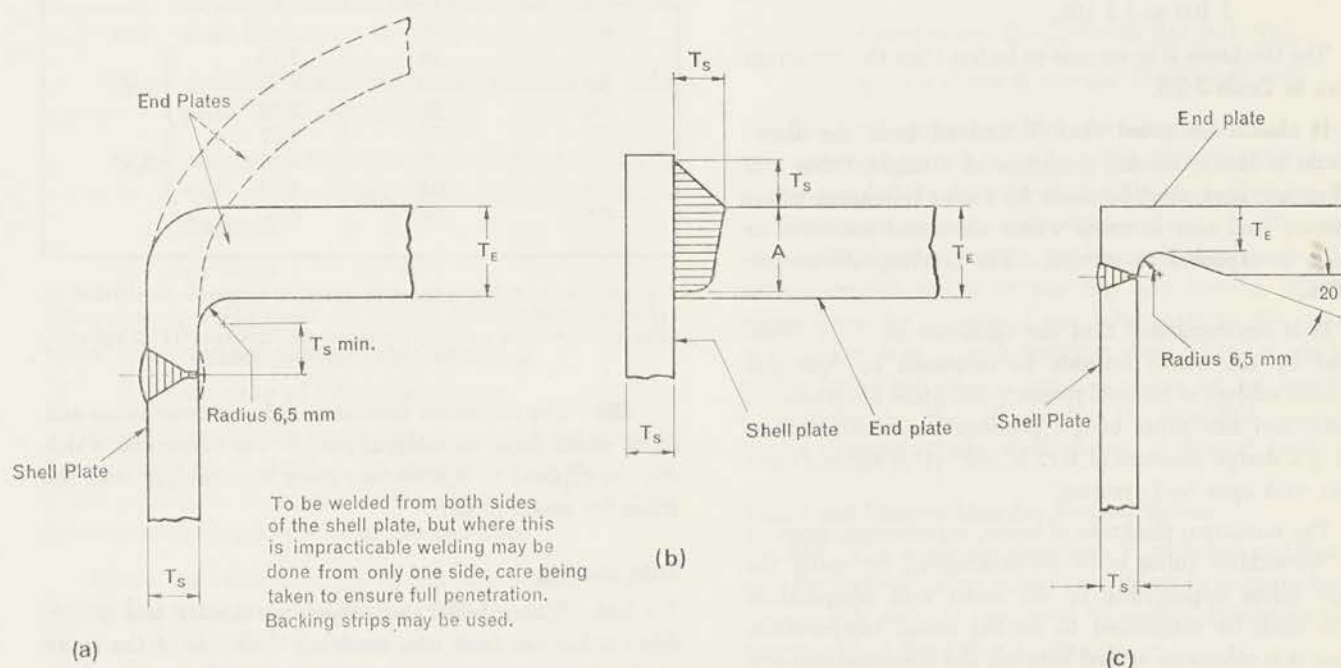


FIG. J 2.13 TYPICAL METHODS OF ATTACHMENT OF HEADER END CLOSURES

$T_s$  = thickness of unpierced shell,

$T_E$  = thickness of end plate,

$A = 2 T_s$  or  $T_E - 1,6$  mm whichever is less.

For end plates welded as shown in Fig. J 2.13(a)

$C = 0,19$  for circular headers,  
 $0,32$  for rectangular headers.

For end plates welded as shown in Figs. J 2.13(b) and J 2.13(c).

$C = 0,28$  for circular headers,  
 $0,40$  for rectangular headers.

Where flat end plates are bolted to flanges attached to the ends of headers the flanges and end plates are to be in accordance with recognized pipe flange standards.

## BOILER TUBES SUBJECT TO INTERNAL PRESSURE

### Minimum Thickness

222 The minimum wall thickness of tubes subject to internal pressure is to be determined by the following formula:—

$$T = \frac{P D_o}{2f + P}$$

where  $T$ ,  $P$ ,  $D_o$  and  $f$  are as defined in J 110, *see also* J 102 and J 105.

The thickness is in no case to be less than the minimum shown in Table J 2.2.

It should be noted that  $T$  derived from the above formula is the minimum thickness of straight tubes and further provision must be made for minus tolerances where necessary and also in cases where abnormal corrosion or erosion is expected in service. For bending allowances, *see* 224.

It is recommended that the thickness of tubes determined by the above formula be increased by  $0,25$  mm for tubes subject to internal pressure and fitted in cylindrical boilers, and also tubes of low pressure water tube boilers having a design pressure of  $1,72$  N/mm<sup>2</sup> ( $17,5$  kgf/cm<sup>2</sup>) and under with open feed systems.

The minimum thickness of boiler, superheater, reheater and economizer tubes is to be determined by using the design stress appropriate to the mean wall temperature which shall be considered to be the metal temperature. Unless it is otherwise agreed between the manufacturer and the Society, the metal temperature used to decide the value of  $f$  for these tubes is to be determined as follows:—

- (a) The calculation temperature for boiler tubes is to be taken as not less than the saturated steam temperature,

plus  $25\text{degC}$  for tubes mainly subject to convection heat,

or plus  $50\text{degC}$  for tubes mainly subject to radiant heat.

- (b) The calculation temperature for superheater and reheater tubes is to be generally taken as not less than the steam temperature expected in the part being considered,

plus  $35\text{degC}$  for tubes mainly subject to convection heat,

or plus  $50\text{degC}$  for tubes mainly subject to radiant heat.

- (c) The calculation temperature for economizer tubes is to be taken as not less than  $35\text{degC}$  in excess of the maximum temperature of the internal fluid

TABLE J 2.2

MINIMUM THICKNESSES OF TUBES

NOMINAL OUTSIDE DIAMETER OF TUBE		MINIMUM THICKNESS	*MINIMUM THICKNESS
Exceeding	Not exceeding		
mm	mm	mm	mm
—	38	1,75	} 2,95
38	50	2,16	
50	70	2,40	
70	75	2,67	} 3,28
75	95	3,05	
95	100	3,28	
100	125	3,50	

\* Applicable to tubes subject to internal pressure and fitted in cylindrical boilers, and also for the tubes of low pressure water tube boilers having a design pressure of  $1,72$  N/mm<sup>2</sup> ( $17,5$  kgf/cm<sup>2</sup>) and under with open feed systems.

223 The minimum thickness of downcomer tubes and pipes which form an integral part of the boiler and which are not exposed to combustion gases is to comply with the Rules for steam pipes.

### Tube Bending

224 Where boiler, superheater, reheater and economizer tubes are bent, the resulting thickness of the tubes at the thinnest part is not to be less than that required for straight tubes, unless it can be demonstrated that the method of forming the bend results in no decrease in strength at the bend as compared with the straight tube. The manufacturer is to demonstrate in connection with any new method of tube bending that this condition is satisfied.



Tube bending and subsequent heat treatment, where necessary, is to be so carried out as to ensure that residual stresses do not adversely affect the strength of the tube for the design purpose intended.

#### Cross-references

225 For details of manholes, sight holes and doors, see J 301 to J 307.

For details of tube holes and fitting of tubes, see J 313.

#### Tube Plates of Vertical Boilers

226 Where vertical boilers have a nest or nests of horizontal tubes so that there is direct tension on the tube plates due to the vertical load on the boiler ends or to their acting as horizontal ties across the shell, the thickness of the tube plates in way of the outer rows of tubes is to be determined by the following formula:—

$$T = \frac{2 P D}{J R_{20}} + 0,75 \text{ mm}$$

where  $T$  and  $P$  are as defined in J 110,

$D$  = twice the radial distance of the centre of the outer row of tube holes from the axis of the shell, in mm,

$R_{20}$  = specified minimum tensile strength of tube plate, in  $\text{N/mm}^2$  ( $\text{kgf/cm}^2$ ),

$J$  = efficiency of ligaments between tube holes in the outer vertical rows (expressed as a fraction),

$$\text{i.e. } J = \frac{(p - d)}{p}$$

where  $p$  = vertical pitch of tubes, in mm,

$d$  = diameter of tube holes, in mm.

Each alternate tube in the outer vertical rows of tubes is to be a stay tube. Further, the arrangement of stay tubes in the nests is to be such that the thickness of the tube plates meet the requirements of 243 and 244.

Where the vertical height of the tube plates between the top and bottom shelves exceeds 0,65 times the internal diameter of the boiler, the staying of the tube plates, and the scantlings of the tube plates and shell plates to which the sides of the tube plates are connected, will require to be specially considered. It is recommended, however, that for this type of boiler, the vertical height of the tube plates between the top and bottom shelves should not exceed 1,25 times the internal diameter of the boiler.

#### Horizontal Shelves of Tube Plates Forming Part of the Shell

227 For vertical boilers of the type referred to in 226, in order to withstand the vertical load due to pressure on the boiler ends the horizontal shelves of the tube plates are to be supported by gussets in accordance with the following formula:—

$$C = \frac{A D_i P}{T}$$

where  $A$  = maximum horizontal dimension of the shelf from the inside of the shell plate to the outside of the tube plate, in mm,

$D_i$  = inside diameter of the boiler, in mm,

$P$  = design pressure, in  $\text{N/mm}^2$  ( $\text{kgf/cm}^2$ ),

$T$  = thickness of the tube plate, in mm.

For the combustion chamber tube plate the minimum number of gussets shall be:—

1 gusset where  $C$  exceeds 25 500 (261 000),

2 gussets where  $C$  exceeds 35 000 (357 000),

3 gussets where  $C$  exceeds 42 000 (428 000).

For the smoke box tube plate the minimum number of gussets shall be:—

1 gusset where  $C$  exceeds 25 500 (261 000),

2 gussets where  $C$  exceeds 47 000 (482 000).

The shell plates to which the sides of the tube plates are connected are not to be less than 1,6 mm thicker than is required by the formula applicable to shell plates with continuous circularity; and where gussets or other stays are not fitted to the shelves, the strength of the parts of the circumferential seams at the top and bottom of these plates from the outside of one tube plate to the outside of the other, is to be sufficient to withstand the whole load on the boiler end with a factor of safety of not less than 4,5 related to  $R_{20}$  ( $R_{20}$  being the specified minimum tensile strength of the shell plates, in  $\text{N/mm}^2$  ( $\text{kgf/cm}^2$ )).

#### Dished and Flanged Ends for Vertical Boilers

228 The minimum thickness,  $T$ , of dished and flanged ends for vertical boilers which are subject to pressure on the concave side and are supported by central uptakes is to be determined by the following formula:—

$$T = \frac{P R_i}{f_2} + 0,75 \text{ mm}$$

where  $T$ ,  $P$  and  $R_i$  are as defined in J 110,

$f_2 = 1,3f$  where  $f$  is as defined in J 110, see also J 105.



The inside radius of curvature,  $R_i$ , of the end plate is not to be greater than the external diameter of the cylinder to which it is attached.

The inside knuckle radius,  $r_i$ , of the arc joining the cylindrical flange to the spherical surface of the end is not to be less than four times the thickness of the end plate and in no case less than 65 mm.

The inside radius of curvature of flange to uptake is not to be less than twice the thickness of the end plate and in no case less than 25 mm.

If the dished end has a manhole the opening is to be strengthened by flanging. The total depth,  $H$ , of the flange, measured from the outer surface of the plate on the minor axis shall be not less than:—

$$H = \sqrt{T W}$$

where  $H$  = depth of flange, in mm,

$T$  = thickness of the plate, in mm,

$W$  = minor axis of the manhole, in mm.

229 The minimum thickness,  $T$ , of dished and flanged ends for vertical boiler furnaces which are subject to pressure on the convex side and are supported by central uptakes is to be determined by the following formula:—

$$T = \frac{P R_o}{f} + 0,75 \text{ mm}$$

where  $T$ ,  $P$ ,  $R_o$  and  $f$  are as defined in J 110.

See also J 102 and J 105.

The inside radii of dishing and flanging is to be as required by 228.

230 The minimum thickness,  $T$ , of dished and flanged ends for vertical boiler furnaces, which are subject to pressure on the convex side and are without support from stays of any kind, is to be determined by the following formula but is in no case to be less than the thickness of the firebox:—

$$T = \frac{C P R_o}{66} + 0,75 \text{ mm}$$

$$\left( T = \frac{C P R_o}{675} + 0,75 \text{ mm} \right)$$

where  $T$  and  $P$  are as defined in J 110,

$R_o$  = outside radius of the crown plate, in mm

In no case is  $\frac{R_o}{T}$  to exceed 88.

$C = \frac{2x}{x+f}$  which must not be taken as less than 0,85 where  $x$  and  $f$  are as defined in 232.

The inside radius of curvature,  $R_i$ , of the end plate is not to be greater than the external diameter of the cylinder to which it is attached.

The inside knuckle radius,  $r_i$ , of the arc joining the cylindrical flange to the spherical surface of the end is not to be less than four times the thickness of the end plate and in no case less than 65 mm.

## CYLINDRICAL FURNACES SUBJECT TO EXTERNAL PRESSURE

NOTE. Furnaces, plain or corrugated, are not to exceed 22,5 mm in thickness.

### Corrugated Furnaces

231 The minimum thickness,  $T$ , of corrugated furnaces is to be determined by the following formula:—

$$T = \frac{P D_o}{C} + 0,75 \text{ mm}$$

where  $P$  is as defined in J 110,

$D_o$  = external diameter of the furnace measured at the bottom of the corrugations, in mm,

$T$  = thickness of the furnace plate measured at the bottom of the corrugations, in mm,

$C = 106$  (1080) for Fox, Morison and Deighton corrugations,

$= 113$  (1150) for Suspension Bulb corrugations.

### Plain Furnaces, Flue Sections and Combustion Chamber Bottoms

232 The minimum thickness,  $T$ , of plain furnaces or furnaces strengthened by the Adamson or other joints, of flue sections and of the cylindrical bottoms of combustion chambers is to be determined by the following formulæ, the greater of the two thicknesses obtained being taken:—

$$T = \sqrt{\frac{P D_o (L + 610)}{10\,240}} + 0,75 \text{ mm} \quad (1)$$

$$\left( T = \sqrt{\frac{P D_o (L + 610)}{104\,400}} + 0,75 \text{ mm} \right)$$

$$T = \frac{C P D_o}{110} + \frac{L}{320} + 0,75 \text{ mm} \quad (2)$$

$$\left( T = \frac{C P D_o}{1120} + \frac{L}{320} + 0,75 \text{ mm} \right)$$



where  $T$  and  $P$  are as defined in J 110,

$D_o$  = external diameter of the furnace, flue or combustion chamber, in mm,

$L$  = length of section between the centres of points of substantial support, in mm,

$$C = \frac{2x}{x+f}$$

$x$  = 0,2% proof stress, in  $N/mm^2$  ( $kgf/cm^2$ ), at a temperature 90degC above the saturated steam temperature corresponding to the design pressure for 410–510  $N/mm^2$  (42–52  $kgf/cm^2$ ) carbon steel Category II material as shown in Chapter Q, Table Q 3.4,

$f$  = minimum specified 0,2% proof stress, in  $N/mm^2$  ( $kgf/cm^2$ ) at temperature 90degC above the saturated steam temperature corresponding to the design pressure for the steel actually used.

### Plain Furnaces of Vertical Boilers

233 The thickness of plain furnaces not exceeding 1700 mm in external diameter is to be determined by the formulæ given in 232; the greater of the two thicknesses being taken:—

where  $D$  = external diameter of the furnace, in mm.  
Where the furnace is tapered, the diameter to be taken for calculation purposes is to be the mean of that at the top and that at the bottom where it meets the substantial support from flange, ring or row of stays,

$L$  = effective length, in mm, of the furnace between the points of substantial support as indicated in Fig. J 2.14.

In no case, however, is the thickness to be more than 22,5 mm. For furnaces under 760 mm in external diameter the thickness is not to be less than 8 mm, and for furnaces 760 mm in external diameter and over, the thickness is not to be less than 9,5 mm. Furnaces exceeding 1700 mm in external diameter shall be the subject of special consideration.

A circumferential row of stays connecting the furnace to the shell shall be considered to provide substantial support to the furnace, provided that:—

- the diameter of the stay be not less than 22,5 mm or twice the thickness of the furnace, whichever is the greater. In the case of screwed stays the diameter is to be measured over the threads.
- the pitch of the stays at the furnace does not exceed 14 times the thickness of the furnace.

### Hemispherical Furnaces

234 The minimum thickness,  $T$ , of unsupported hemispherical furnaces subject to pressure on the convex surface is to be determined by the following formula:—

$$T = \frac{C P R_o}{60,8} + 0,75 \text{ mm} \quad \left( T = \frac{C P R_o}{620} + 0,75 \text{ mm} \right)$$

where  $T$  and  $P$  are as defined in J 110,

$R_o$  = outer radius of curvature of the furnace, in mm,

$C = \frac{2x}{x+f}$  which must not be taken as less than 0,85.

$x$  and  $f$  are as defined in 232.

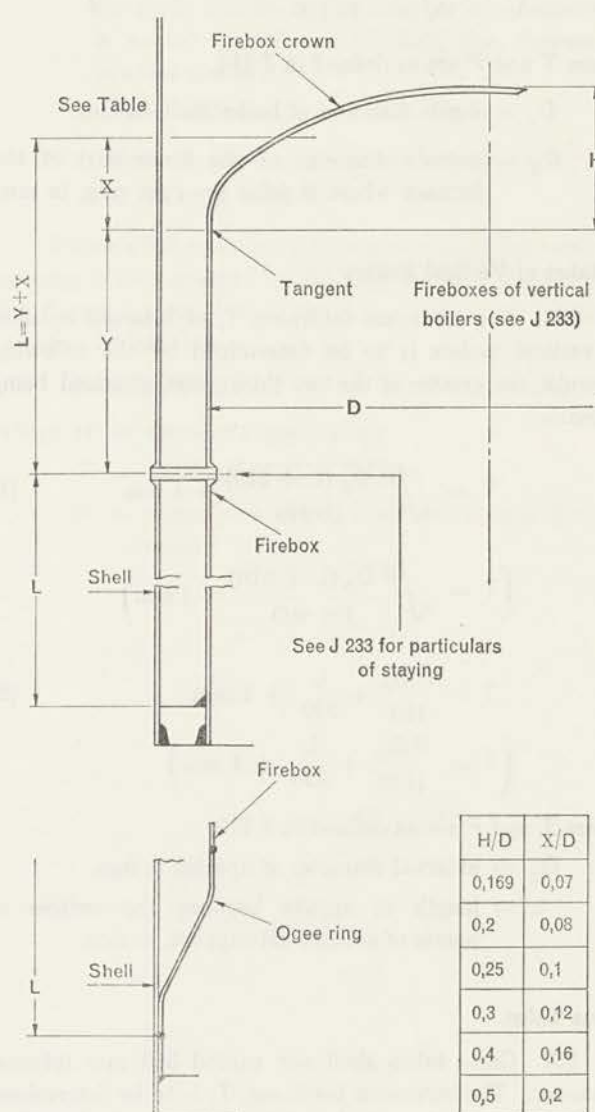


FIG. J 2.14 EFFECTIVE LENGTH,  $L$ , FOR USE IN J 233

In no case, however, is  $T$  to exceed 22,5 mm and the ratio  $\frac{R_o}{T - 0,75}$  to exceed 100.

### Ogee Rings

235 The minimum thickness,  $T$ , of the ogee ring which connects the bottom of the furnace to the shell of a vertical boiler and sustains the whole vertical load on the furnace is to be determined by the following formula:—

$$T = \sqrt{\frac{P D_i (D_i - D_o)}{990}} + 0,75 \text{ mm}$$

$$\left( T = \sqrt{\frac{P D_i (D_i - D_o)}{10110}} + 0,75 \text{ mm} \right)$$

where  $T$  and  $P$  are as defined in J 110,

$D_i$  = inside diameter of boiler shell, in mm,

$D_o$  = outside diameter of the lower part of the furnace where it joins the ogee ring, in mm.

### Uptakes of Vertical Boilers

236 The minimum thickness,  $T$ , of internal uptakes of vertical boilers is to be determined by the following formulae, the greater of the two thicknesses obtained being taken:—

$$T = \sqrt{\frac{P D_o (L + 610)}{10240}} + 4 \text{ mm} \quad (1)$$

$$\left( T = \sqrt{\frac{P D_o (L + 610)}{104400}} + 4 \text{ mm} \right)$$

$$T = \frac{P D_o}{110} + \frac{L}{320} + 4 \text{ mm} \quad (2)$$

$$\left( T = \frac{P D_o}{1120} + \frac{L}{320} + 4 \text{ mm} \right)$$

where  $T$  and  $P$  are as defined in J 110,

$D_o$  = external diameter of uptake, in mm,

$L$  = length of uptake between the centres of points of substantial support, in mm.

### Cross Tubes

237 Cross tubes shall not exceed 300 mm internal diameter. The minimum thickness,  $T$ , is to be determined by the following formula but is in no case to be less than 9,5 mm.

$$T = \frac{P D_i}{44} + 6,5 \text{ mm} \quad \left( T = \frac{P D_i}{450} + 6,5 \text{ mm} \right)$$

where  $T$  and  $P$  are as defined in J 110,

$D_i$  = internal diameter of cross tube, in mm.

### Stayed Flat Surfaces

238 Where flat end plates are flanged for connection to the shell, the inside radius of flanging is not to be less than 1,75 times the thickness of the plate, with a minimum of 38 mm.

Where combustion chamber or firebox plates are flanged for connection to the wrapper plate, the inside radius of flanging is to be equal to the thickness of the plate, with a minimum of 25 mm.

Where unflanged flat plates are connected to the shell by welding, the methods of attachment are to be as shown in Fig. J 2.15. Similar forms of attachment may be used where unflanged combustion chamber or fire box plates are connected to the wrapper plate by welding.

239 Where the flange curvature is a point of support, this is to be taken at the commencement of curvature, or at a line 3,5 times the thickness of the plate measured from the outside of the plate, whichever is nearer to the flange.

Where a flat plate is welded directly to a shell or wrapper plate, the point of support is to be taken at the inside of the shell or wrapper plate.

240 The thickness,  $T$ , of those portions of flat plates supported by stays is to be determined by the following formula:—

$$T = C d \sqrt{\frac{P}{f_1}} + 0,75 \text{ mm}$$

where  $T$  and  $P$  are as defined in J 110,

$f_1 = 0,85 f$  where  $f$  is as defined in J 110, see also J 102 and J 105,

$d = \sqrt{A^2 + B^2}$  where the stays are regularly pitched,

$A$  being the horizontal pitch of the stays and

$B$  the vertical pitch of the stays.

Where the stays are irregularly pitched, then

$d$  = diameter of the largest circle which can be drawn through three points of support without enclosing another point of support. Only two points of support may lie on one side of any diameter of the circle.

Where a flange is taken as a point of support, the circumference of the circle is to be tangent to the line of curvature (see 239).



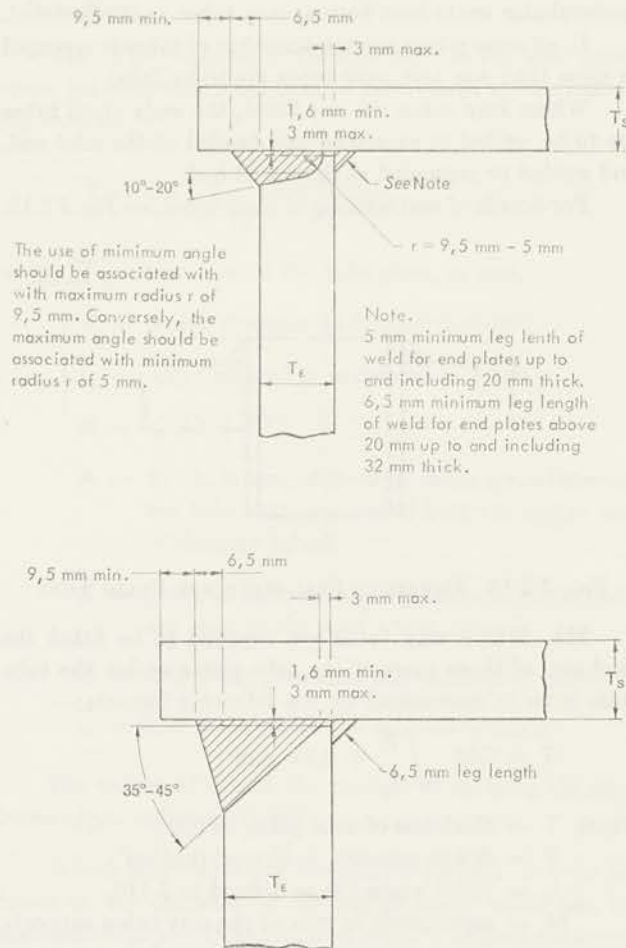


FIG. J 2.15 ATTACHMENT OF UNFLANGED FLAT END PLATES TO SHELL

$T_S$  = thickness of cylindrical shell

$T_E$  = thickness of flat end

$C$  = a constant, depending on the method of support as detailed below. Where various forms of support are used the constant,  $C$ , is to be the mean of the values for the respective methods adopted.

Alternative methods of support will be specially considered.

All constants given in this paragraph relate to plates which are stress relieved and not exposed to flame. Where the plates are exposed to flame the thickness of the plate is to be increased by 10 per cent.

The value of  $C$  in the above formula is to be as follows:—

- (a) Where plain stays are strength welded into the plates as shown in Fig. J 2.16:

$$C = 0.39.$$

- (b) Where plain bar stays pass through holes in the plates and are fitted on the outside with washers as shown in Fig. J 2.17:

$$C = 0.35 \text{ where the diameter of the washer is } 3.5 \text{ times the diameter of the stay.}$$

$$C = 0.33 \text{ where the diameter of the washer is } 0.67 \text{ times the pitch of the stays.}$$

- (c) Where the flat plate is flanged for attachment to the shell, flue, furnace or wrapper or alternatively is welded directly to the shell, flue, furnace or wrapper (see 239):

$$C = 0.33.$$

- (d) Where the support is a gusset or link stay:

$$C = 0.39.$$

Where a flat plate has a manhole or sight hole and the opening is strengthened by flanging, the total depth,  $H$ , of the flange, measured from the outer surface of the plate, is not to be less than:—

$$H = \sqrt{TW}$$

where  $H$  = depth of flange, in mm,

$T$  = thickness of plate, in mm,

$W$  = minor axis of the manhole or sight hole, in mm.

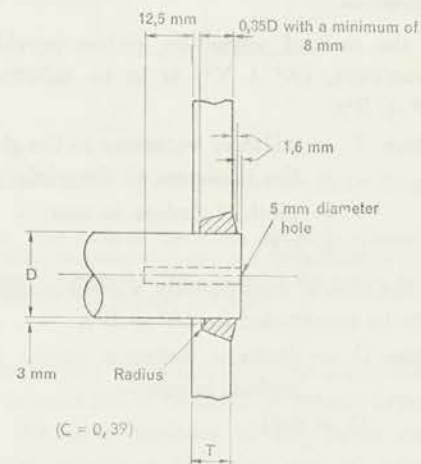


FIG. J 2.16 ATTACHMENT OF FIREBOX, COMBUSTION CHAMBER STAYS AND BAR STAYS

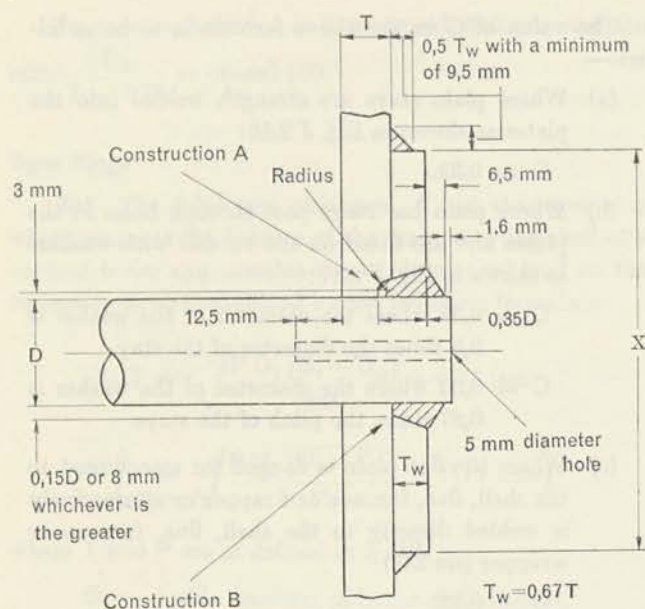


FIG. J 2.17 ATTACHMENT OF BAR STAYS

Method of construction "A" or "B" may be used except where  $T_w$  is less than  $0.35D$  when the form of construction shown in "A" is to be used.

DIAMETER OF WASHER "X"	VALUE OF CONSTANT C
$X = 3.5D$	0.35
$X = 0.67$ pitch of stays	0.33

241 Where the flat top plates of combustion chambers are supported by welded-on girders the equation in 240 is to apply as follows:—

- (a) In the case of welded-on girders provided with waterways,  $(X^2 + Y^2)$  is to be substituted for  $(A^2 + B^2)$ .

where  $X$  = width of waterway in the girder plus the thickness of the girder, in mm,

$Y$  = pitch of girders, in mm:—

$C = 0.42$ .

- (b) In the case of continuously welded-on girders,  $D^2$  is to be substituted for  $(A^2 + B^2)$ ,

where  $D$  = distance between inside faces of girders, in mm:—

$C = 0.51$ .

#### Flat Tube Plates within the Tube Nests

242 Where the total number of tubes is arranged in one nest, the area of which exceeds  $0.65 \text{ m}^2$  in the case of

directly fired multitubular boilers, and  $2 \text{ m}^2$  in the case of multitubular waste heat boilers, stay tubes are to be fitted.

In all cases where the total number of tubes is arranged in more than one nest, stay tubes are to be fitted.

Where stay tubes are not fitted, the ends of all tubes are to be welded or expanded and beaded at the inlet end, and welded or expanded at the outlet end.

For details of seal welding of plain tubes, see Fig. J 2.18.

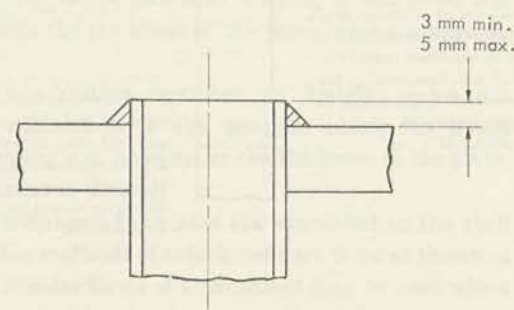


FIG. J 2.18 DETAIL OF SEAL-WELD FOR PLAIN TUBE

243 Where stay tubes are required to be fitted the thickness of those parts of the tube plates within the tube nests is to be determined by the following formula:—

$$T = CM \sqrt{\frac{P}{f_s}} + 0.75 \text{ mm}$$

where  $T$  = thickness of tube plate, in mm,

$P$  = design pressure, in  $\text{N/mm}^2$  ( $\text{kgf/cm}^2$ ),

$f_s = 0.85 f$  where  $f$  is as defined in J 110,

$M$  = mean pitch, in mm, of the stay tubes supporting any positions of the plate (being the sum of the four sides of any quadrilateral divided by 4),

$C = 0.42$  for plates not exposed to flame with stay tubes secured as shown in Fig. J 2.19,

$C = 0.46$  for plates exposed to flame.

Where the area of the tube nest does not exceed  $0.65 \text{ m}^2$  in the case of direct fired boilers or  $2 \text{ m}^2$  in the case of waste heat boilers, and stay tubes are not fitted, the thickness of the tube plates is to be determined by the above formula:—

where  $M$  = four times the mean pitch, in mm, of the plain tubes in the nest,

$C = 0.45$  for plates not exposed to flame,

$C = 0.49$  for plates exposed to flame.

The thickness,  $T$ , of any tube plate in the tube area is not to be less than:—

- (a) 12.5 mm where the diameter of the tube hole does not exceed 50 mm, and

- (b) 14 mm where the diameter of the tube hole is greater than 50 mm.



### Flat Tube Plates between Wide Water Spaces and around Tube Nests

244 The thickness of the tube plate in the wide water space between tube nests is to be determined by the following formula:—

$$T = Cd \sqrt{\frac{P}{f_s}} + 0,75 \text{ mm.}$$

where  $T$  = thickness of the tube plate, in mm,

$P$  = design pressure, in  $\text{N/mm}^2$  ( $\text{kgf/cm}^2$ ),

$f_s = 0,85 f$  where  $f$  is as defined in J 110,

$$d = \sqrt{A^2 + B^2},$$

$A$  = width, in mm, of the wide water space between the tube nests (measured from the centre line of the stay tubes),

$B$  = pitch, in mm, of the stay tubes in the boundary rows of the wide water space.

$C = 0,42$  if the plates are not exposed to flame,

$C = 0,46$  if the plates are exposed to flame.

The values of  $C$  and the method of securing the stay tubes are as indicated in 243.

Where stay tubes are irregularly pitched,  $d$  is to be taken as the diameter of the largest circle which can be drawn through any three points of support without enclosing another point of support. Where various forms of support are used, the value of  $C$  is to be the mean of the values for the respective methods adopted.

For the portions of the end plates between the top rows of tubes and the steam space stays, the above formula is to apply,  $B$  being taken as the distance between the centre line of the top row of tubes and the centre of the bar stays or other point of support, and  $A$  being taken as:—

$$\frac{A_1 + A_2}{2}$$

where  $A_1$  is the horizontal distance between the centres of bar stays or other method of support, and

$A_2$  is the horizontal distance between the centre of one stay tube and the centre of the next stay tube in the top boundary row.

Where no stay tubes are fitted,  $A_2$  is to be taken as equal to four times the horizontal pitch of the plain tubes.

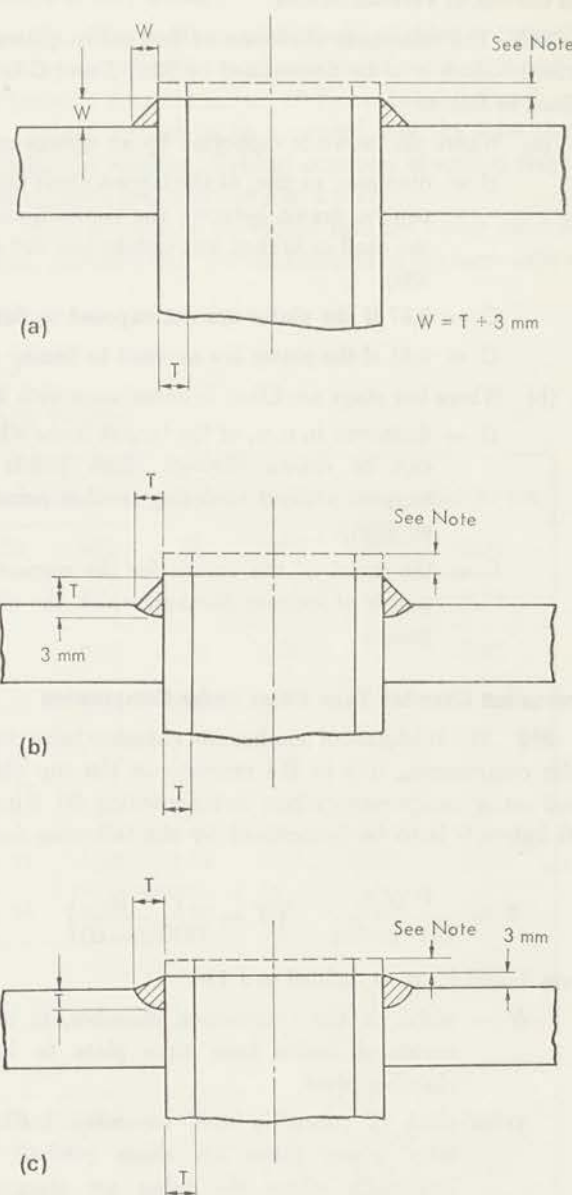


FIG. J 2.19 ATTACHMENT OF STAY TUBES

NOTE. The ends of the tubes are to be dressed flush with the welds when exposed to flame or comparatively high temperature. When not exposed, the ends of the tubes may extend a maximum of 9,5 mm beyond the weld.

Where no stay tubes are fitted the support afforded by the plain tubes is not to be taken to extend beyond the line enclosing the outer surfaces of the tubes except that, between the outside of the wing row of tubes and the attachment of the end plate to shell, there may be an unsupported width equal to the flat plate margin as given by 248, formula (1).

**Flat Crowns of Vertical Boilers**

245 The minimum thickness of flat crown plates of vertical boilers is to be determined by 240;  $d$  and  $C$  being defined as follows:—

(a) Where the crown is supported by an uptake only,

$d$  = diameter, in mm, of the largest circle which can be drawn between the connections to the shell or firebox and uptake (*see* 238 and 239),

$C$  = 0,47 if the plates are not exposed to flame,

$C$  = 0,51 if the plates are exposed to flame.

(b) Where bar stays are fitted in accordance with 240,

$d$  = diameter, in mm, of the largest circle which can be drawn through three points of support without enclosing another point of support,

$C$  = the mean of the values for the respective points of support through which the circle passes.

**Combustion Chamber Tube Plates under Compression**

246 The thickness of combustion chamber tube plates under compression, due to the pressure on the top plate, based on a compressive stress not exceeding 96 N/mm<sup>2</sup> (980 kgf/cm<sup>2</sup>) is to be determined by the following formula:—

$$T = \frac{P W p}{193 (p-d)} \quad \left( T = \frac{P W p}{1970 (p-d)} \right)$$

where  $T$  and  $P$  are as defined in J 110,

$W$  = width of the combustion chamber, in mm, measured inside from tube plate to back chamber plate,

$p$  = pitch of tubes, in mm, measured horizontally where tubes are chain pitched, or diagonally where the tubes are staggered pitched and the diagonal pitch is less than the horizontal pitch,

$d$  = internal diameter of the plain tubes, in mm.

**Girders for Combustion Chamber Top Plates**

247 The proportions of steel plate girders supporting the tops of combustion chambers is to be determined by the following formula:—

$$T = \frac{3,2 P l^2 p}{d^2 R_{20}}$$

where  $T$  and  $P$  are as defined in J 110,

$d$  = depth of girder, in mm,

$l$  = length of girder, in mm, measured inside from tube plate to back chamber plate,

$p$  = distance apart of the girders, in mm,

$R_{20}$  = specified minimum tensile strength of the girder plate, in N/mm<sup>2</sup> (kgf/cm<sup>2</sup>).

The above formula is applicable to plate girders welded continuously to the top combustion chamber plate by means of a full penetration weld.

**Flat Plate Margins**

248 The width of margin,  $b$ , of a flat plate which may be regarded as being supported by the shell, furnaces or flues to which the flat plate is attached is not to exceed that determined by the following formula:—

$$b = \frac{C (T - 0,75 \text{ mm})}{\sqrt{P}}$$

where  $T$  and  $P$  are as defined in J 110,

$b$  = width of margin, in mm,

$C$  = 9,8 (31,3) for plates not exposed to flame,

$C$  = 9,1 (29,2) for plates exposed to flame.

Where an unflanged flat plate is welded directly to the shell, furnaces or flues and it is not practicable to effect the full penetration weld from both sides of the flat plate, the constant  $C$  used in the above formula is to be:—

$C$  = 7,45 (23,9) for plates not exposed to flame,

$C$  = 7,05 (22,5) for plates exposed to flame.

In the case of plates which are flanged, the margin is to be measured from the commencement of curvature of flanging, or from a line 3,5 times the thickness of the plate measured from the outside of the plate, whichever is nearer to the flange.

Where the flat plate is not flanged for attachment to the shell, furnaces or flues, the margin is to be measured from the inside of the shell or the outside of the furnaces or flues, whichever is applicable.

In no case, however, is the diameter  $D$ , in mm, of the circle forming the boundary of the margin supported by the uptake of a vertical boiler to be greater than determined by the following formula:—

$$D = \sqrt{\frac{34,5 A}{P} + d^2}$$

$$\left( D = \sqrt{\frac{352 A}{P} + d^2} \right)$$

where  $A$  = cross-sectional area of the uptake tube, in mm<sup>2</sup>,

$P$  = design pressure, in N/mm<sup>2</sup> (kgf/cm<sup>2</sup>),

$d$  = external diameter of uptake, in mm.



# BOILER TUBES SUBJECT TO EXTERNAL PRESSURE INCLUDING PLAIN AND STAY SMOKE TUBES FOR CYLINDRICAL BOILERS

## Stay Tubes

249 Each stay tube is to be designed to carry its due proportion of the load on the plates which it supports. No stay tube is to be less than 5 mm thick at its thinnest part.

## Welded-in Stay Tubes

250 The thickness of stay tubes welded to tube plates is to be such that the maximum stress on the thinnest part of the tube does not exceed 69 N/mm<sup>2</sup> (705 kgf/cm<sup>2</sup>).

Stay tubes are to be expanded into the tube plate in addition to welding. Typical examples of welded stay tube attachments are shown in Fig. J 2.19.

Stay tubes may be welded into the boiler after stress relief, provided they are not adjacent in the same tube nest.

TABLE J 2.3  
THICKNESS OF PLAIN TUBES

DESIGN PRESSURE in N/mm <sup>2</sup>	OUTSIDE DIAMETER in mm											THICKNESS
	38	44,5	51	57	63,5	70	76	82,5	89	95	102	mm
										2,69	2,52	5,89
								2,62	2,41	2,28	2,14	5,38
							2,41	2,21	2,07	1,93	1,79	4,88
				2,76	2,48	2,28	2,07	1,93	1,79	1,66	1,59	4,47
		2,93	2,55	2,28	2,07	1,89	1,73	1,59	1,48	1,37	1,27	4,06
	2,66	2,28	2,07	1,79	1,59	1,48	1,31	1,24	1,14	1,03	0,96	3,66
	2,03	1,69	1,48	1,31	1,21	1,10	0,96	0,89	0,82	0,76	0,69	3,25
	1,48	1,24	1,07	0,96	0,86	0,76						2,95

DESIGN PRESSURE in kgf/cm <sup>2</sup>	OUTSIDE DIAMETER in mm											THICKNESS
	38	44,5	51	57	63,5	70	76	82,5	89	95	102	mm
										27,4	25,7	5,89
								26,7	24,6	23,2	21,8	5,38
							24,6	22,5	21,1	19,7	18,3	4,88
				28,1	25,3	23,2	21,1	19,7	18,3	16,9	16,2	4,47
		29,9	26,0	23,2	21,1	19,3	17,6	16,2	15,1	14,0	13,0	4,06
	27,1	23,2	21,1	18,3	16,2	15,1	13,4	12,6	11,6	10,5	9,8	3,66
	20,7	17,2	15,1	13,4	12,3	11,2	9,8	9,1	8,4	7,7	7,0	3,25
	15,1	12,6	10,9	9,8	8,8	7,7						2,95



**Plain Tubes**

251 The thickness of plain tubes is to be in accordance with Table J 2.3 for the appropriate outside diameter and design pressure.

Plain tubes may be seal welded at both ends, seal welded at the inlet end and expanded at the outlet end, or expanded at both ends.

Where plain tubes are seal welded, the weld detail is to be as shown in Fig. J 2.18 and the tubes are to be expanded into the tube plates in addition to welding.

Where plain tubes are expanded only, the process is to be carried out with roller expanders, and the expanded portion of the tube is to be parallel through the full thickness of the tube plate. In addition to expanding, tubes may be bell-mouthed or beaded at the inlet end.

Where the total number of tubes is arranged in one nest and no stay tubes are fitted, *see* 242, the ends of all tubes are to be welded or expanded and beaded at the inlet end, and welded or expanded at the outlet end.

**Pitch of Tubes**

252 The spacing of tube holes is to be such that the minimum width, in mm, of any ligament between the tube holes is not less than:—

$$0,125 d + 12,5 \text{ mm}$$

where  $d$  = diameter of the tube hole, in mm.

**Combustion Chambers and Longitudinal Bar Stays**

253 The permissible stress in combustion chamber and other similar bar stays, calculated on the minimum sectional area, is not to exceed  $62 \text{ N/mm}^2$  ( $633 \text{ kgf/cm}^2$ ). The diameter of any stay is not to be less than 19 mm.

254 The permissible stress in longitudinal stays, calculated on the minimum cross-sectional area, is not to exceed

$\frac{\text{minimum specified tensile strength in } \text{N/mm}^2 \text{ (kgf/cm}^2\text{)}}{5,3}$
-----------------------------------------------------------------------------------------------------

In no case is the diameter of the stay at any section to be less than 25 mm.

**Loads on Stay Tubes and Bar Stays**

255 Stay tubes and bar stays are to be designed to carry the whole load due to the pressure on the area to be supported.

For a stay tube or bar stay, the net area to be supported is to be the area, in  $\text{mm}^2$ , enclosed by the lines bisecting at right angles the lines joining the stay and the adjacent points of support, less the area of any tubes or stays

embraced. In the case of a stay tube or bar stay in the boundary rows the support afforded by the flat plate margin, where applicable, should be taken into account.

Where there are no stay tubes in the tube nest, the area to be supported by a bar stay is to extend to the tangential boundary of the tube nest.

**Section 3****CONSTRUCTION****Access Arrangements**

301 In watertube boilers, manholes are to be provided in all drums of sufficient size to permit access for internal examination and cleaning and for fitting and expanding the tubes. In the case of headers for water walls, superheaters or economizers and of drums which are too small to permit entry, sight holes or mudholes sufficiently large and numerous for these purposes are to be provided.

302 Cylindrical boilers are to be provided, where possible, with means for ingress to permit examination and cleaning of the inner surfaces of plates and tubes exposed to flame. Where the boilers are too small to permit this there are to be sight holes and mudholes sufficiently large and numerous to permit the inside to be satisfactorily cleaned.

303 Where the cross tubes of vertical boilers are large there is to be a sight hole in the shell opposite to one end of each tube sufficiently large to permit the tube to be examined and cleaned. These sight holes are to be in positions accessible for that purpose.

304 Unfired pressure vessels are to be so made that the internal surfaces may be examined and, wherever practicable, the openings for this purpose are to be sufficiently large for access and for cleaning the inner surfaces.

305 Manholes in cylindrical shells are to have their shorter axes arranged longitudinally, and are to be located clear of the welded joints in the shell.

306 Doors for manholes, mudholes and sight holes are to be formed from steel plate or of other approved construction and all jointing surfaces are to be machined.

The doors are to be of the internal type and are to be provided with spigots which have a clearance of not more than 1,5 mm all round, i.e. the axes of the opening are not to exceed those of the door by more than 3 mm.

307 Doors for openings not larger than  $230 \text{ mm} \times 180 \text{ mm}$  need only be fitted with one stud which may be forged integral with the door. Larger doors are to be



provided with two studs screwed through the door and fitted with nuts on the inside or alternatively, bolts may be used screwed through the door with the heads inside; other methods of attachment may be accepted provided details are submitted for consideration.

The crossbars or dogs are to be of steel.

For smaller circular openings in headers and similar fittings an approved type of plug may be used.

### Torispherical and Semi-ellipsoidal Ends

308 For typical acceptable types of dished end to cylindrical shell attachments, and for limitations, see Fig. J 3.1. Types (d) and (e) are to be made a tight fit in the cylindrical shell.

Where the difference in thickness is the same throughout the circumference, the thicker plate is to be reduced in thickness by machining to a taper for a distance not less than four times the offset so that the two plates are of equal thickness at the position of the circumferential weld. A parallel portion may be provided between the end of the

taper and the weld edge preparation; alternatively, if so desired, the width of the weld may be included as part of the smooth taper of the thicker plate (see J 510).

The thickness of the plates at the position of the circumferential weld is to be not less than that of an unpierced cylindrical shell of seamless or welded construction, whichever is applicable, of the same diameter and material (see J 209).

### Hemispherical Ends

309 Where hemispherical ends are butt welded to cylindrical shells, the thickness of the shell is to be reduced by taper to that of the end, and the centre of the hemisphere is to be so located that the entire tapered portion of the shell and the butt weld are within the hemisphere (see Fig. J 3.2).

If the hemispherical end is provided with a parallel portion, the thickness of this portion is to be not less than that of a seamless or welded shell, whichever is applicable, of the same diameter and material.

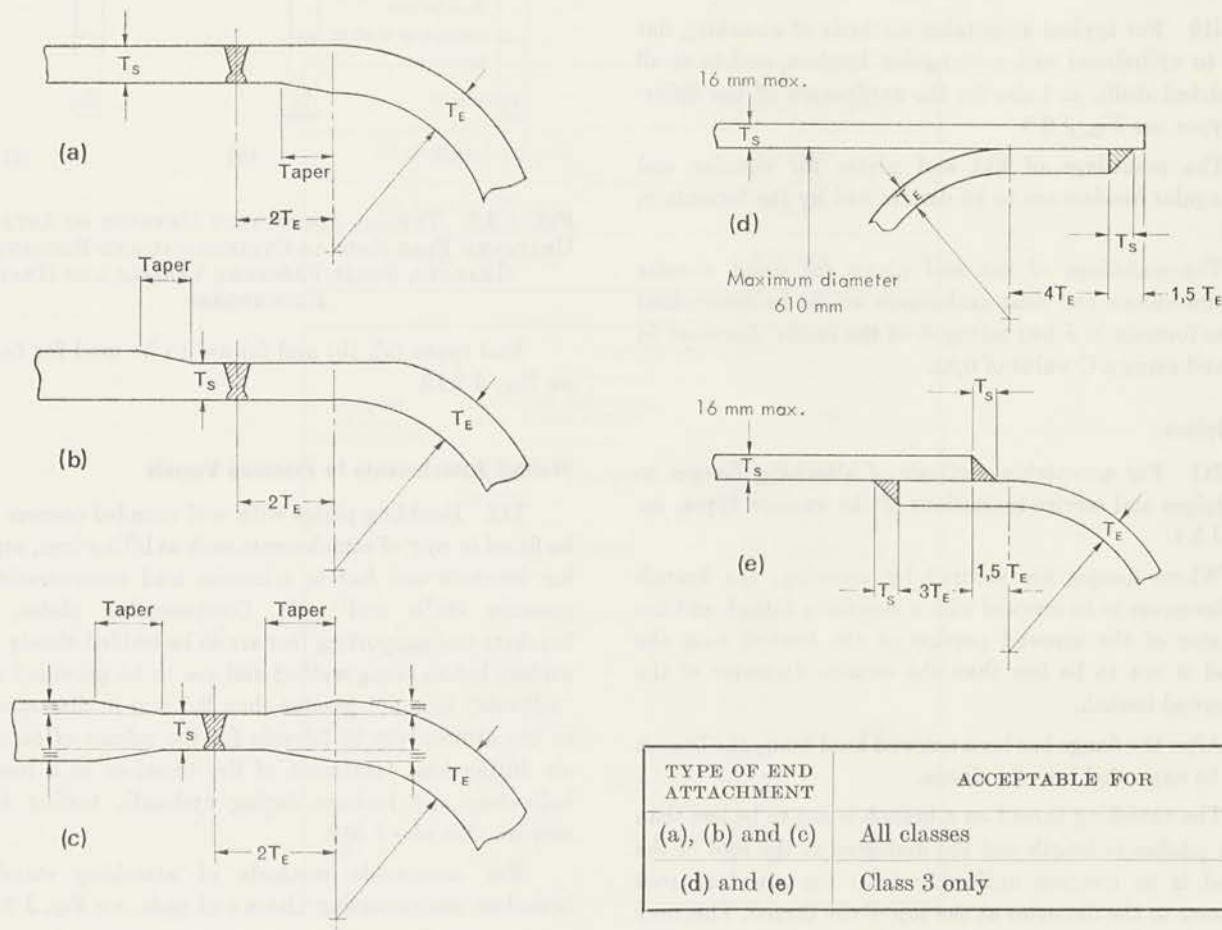


FIG. J 3.1 TYPES OF ATTACHMENT OF DISHED ENDS TO CYLINDRICAL SHELLS

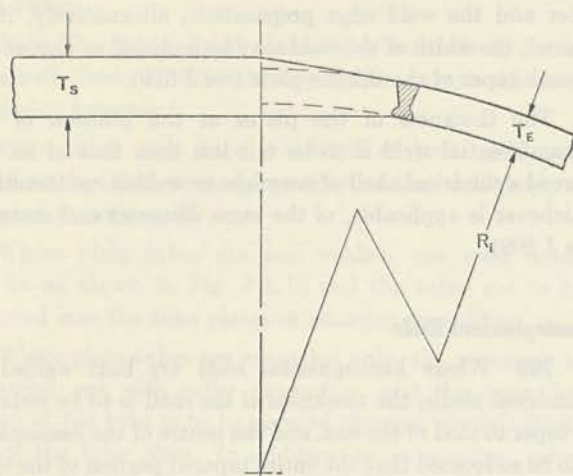


FIG. J 3.2 ATTACHMENT OF HEMISPHERICAL END TO CYLINDRICAL SHELL

#### Flat End Plates

310 For typical acceptable methods of attaching flat ends to cylindrical and rectangular headers, and to small cylindrical shells, and also for the application of the different types, see Fig. J 3.3.

The scantlings of flat end plates for circular and rectangular headers are to be determined by the formula in J 221.

The scantlings of flat end plates for small circular pressure vessels and heat exchangers are to be determined by the formula in J 240 taking  $d$  as the inside diameter in mm and using a  $C$  value of 0,33.

#### Standpipes

311 For acceptable methods of attaching flanges to standpipes and service limitations of the various types, see Fig. J 3.4.

Where flanges are secured by screwing, the branch and flange are to be screwed with a vanishing thread, and the diameter of the screwed portion of the branch over the thread is not to be less than the outside diameter of the unscrewed branch.

After the flange has been screwed hard home the branch is to be expanded into the flange.

The vanishing thread on a branch is not to be less than three pitches in length and the diameter at the root of the thread is to increase uniformly from the standard root diameter to the diameter at the top of the thread. This may be produced by suitably grinding the dies, and the flange should be tapered out to the same formation.

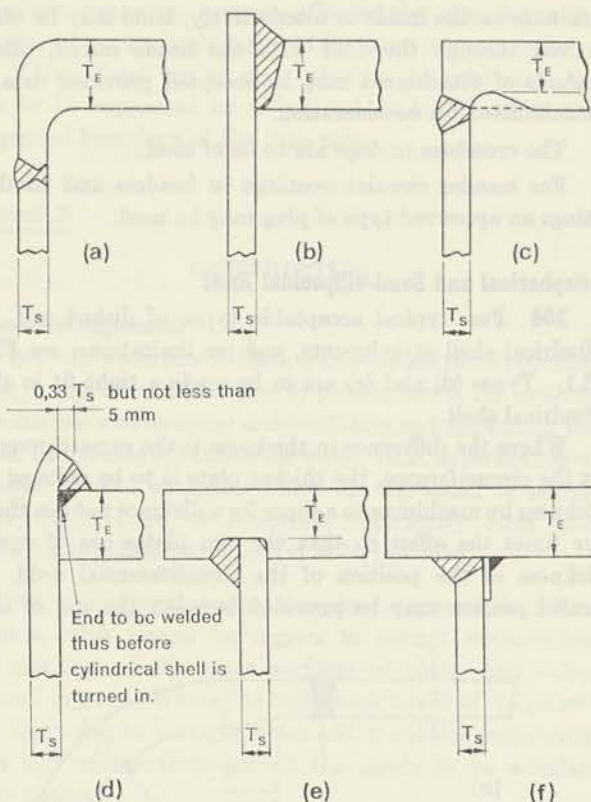


FIG. J 3.3 TYPICAL ACCEPTABLE METHODS OF ATTACHING UNSTAYED FLAT ENDS TO CYLINDRICAL AND RECTANGULAR HEADERS, SMALL PRESSURE VESSELS AND HEAT EXCHANGERS

End types (a), (b) and (c) are to be used for headers, see Fig. J 2.13.

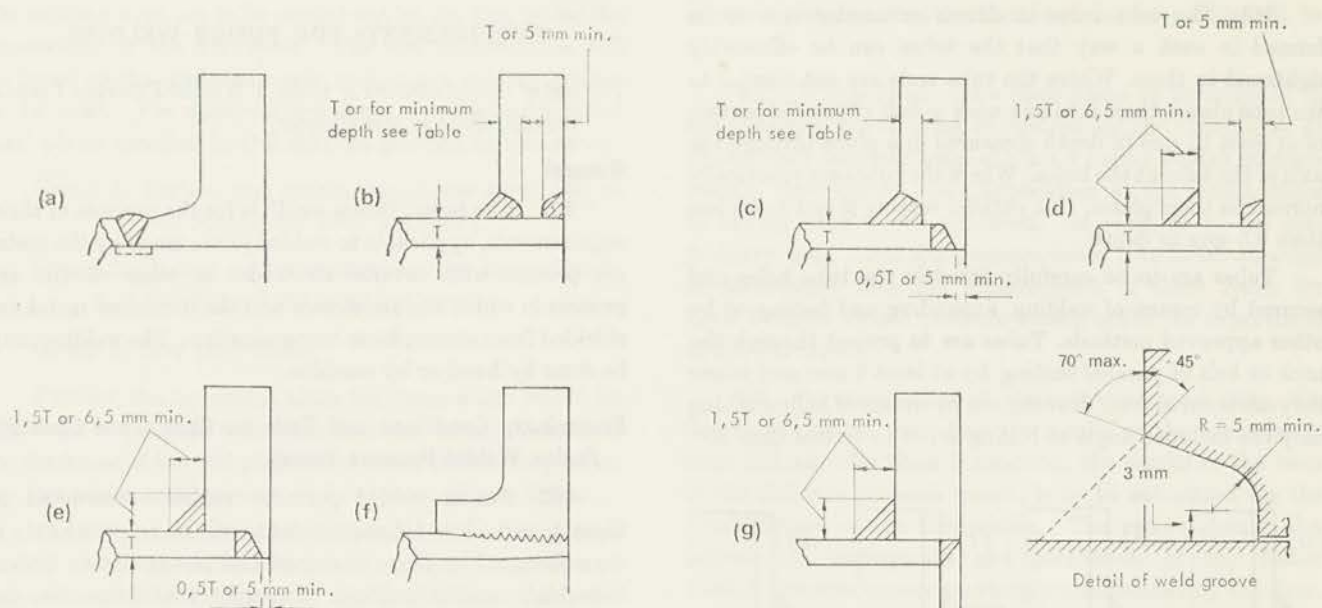
#### Welded Attachments to Pressure Vessels

312 Doubling plates with well rounded corners are to be fitted in way of attachments such as lifting lugs, supporting brackets and feet to minimise load concentrations on pressure shells and ends. Compensating plates, pads, brackets and supporting feet are to be bedded closely to the surface before being welded and are to be provided with a "tell-tale" hole not greater than 9,5 mm in diameter open to the atmosphere to provide for the release of entrapped air during heat treatment of the vessel or as a means of indicating any leakage during hydraulic testing and in service. See also J 512.

For acceptable methods of attaching standpipes, branches, compensating plates and pads, see Fig. J 3.5.

Alternative methods of attachment may be accepted provided details are submitted for consideration.





PIPE BORE	MINIMUM DEPTH OF GROOVE FOR FLANGES (b) AND (c)
13 mm and 19 mm	6,5 mm
25 mm to 38 mm	8 mm
50 mm and over	9,5 mm

TYPE OF FLANGE ATTACHMENT	SERVICE AND RATING			
	FEED, AIR, OIL FUEL AND OTHER FLUIDS		STEAM	
	Pressure N/mm <sup>2</sup> (kgf/cm <sup>2</sup> )	Temperature °C	Pressure N/mm <sup>2</sup> (kgf/cm <sup>2</sup> )	Temperature °C
(a)	All Conditions		All Conditions	
(b) & (c)	All Conditions		5,15 (52,5)	454
(d) & (e)	5,15 (52,5)	260	3,78 (38,5)	400
(f)	4,12 (42)		3,09 (31,5)	
(g)	1,72 (17,5)		1,72 (17,5)	260

FIG. J 3.4 ACCEPTABLE METHODS OF ATTACHING FLANGES TO STEEL BRANCHES OR STANDPIPES

**Fitting of Tubes in Water Tube Boilers**

313 The tube holes in drums or headers are to be formed in such a way that the tubes can be effectively tightened in them. Where the tube ends are not normal to the tube plates, there is to be a neck or belt of parallel seating of at least 13 mm in depth measured in a plane through the axis of the tube at the holes. Where the tubes are practically normal to their plates, this parallel seating is not to be less than 9,5 mm in depth.

Tubes are to be carefully fitted in the tube holes and secured by means of welding, expanding and belling or by other approved methods. Tubes are to project through the neck or belt of parallel seating by at least 6 mm and where they are secured from drawing out by means of bellmouthing only the included angle of belling is not to be less than 30°.

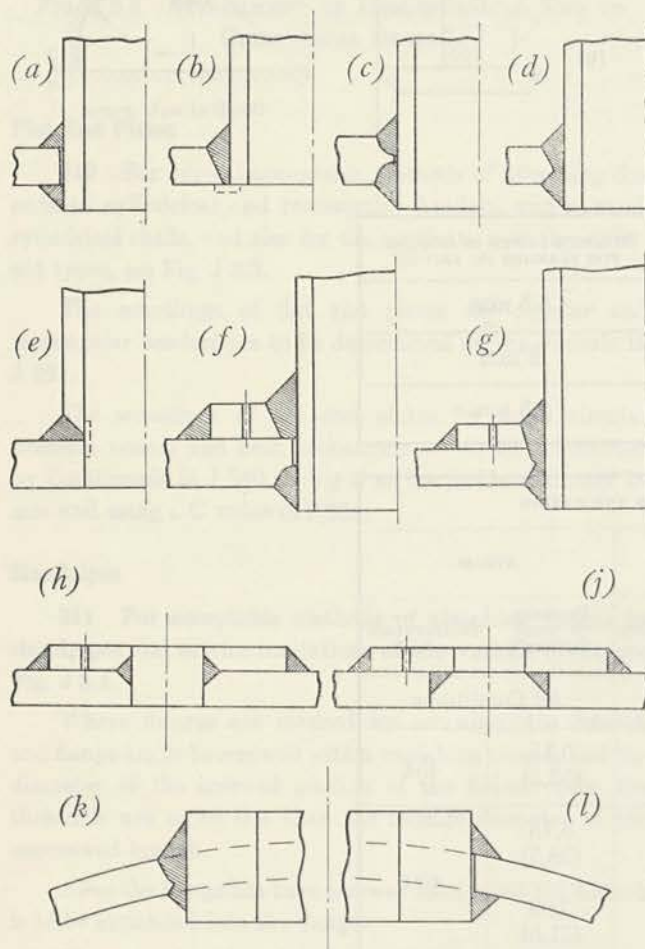


FIG. J 3.5 TYPICAL ACCEPTABLE METHODS OF ATTACHING BRANCHES AND PADS

Types (a) and (l) attachments are not to be used for openings which require to be compensated. Backing rings may be used with types (b) and (e).

**Section 4****REQUIREMENTS FOR FUSION WELDING**

*For list of manufacturers of Class 1 Welded Pressure Vessels, see Appendix to this Chapter.*

**General**

401 The term "fusion weld" is for the purpose of these requirements, applicable to welded joints made by the metal arc process with covered electrodes or other electric arc process in which the arc stream and the deposited metal are shielded from atmospheric contamination. The welding may be done by hand or by machine.

**Preliminary Conditions and Tests for Class 1 and Class 2/1 Fusion Welded Pressure Vessels**

402 Fusion welded pressure vessels constructed to Class 1 and Class 2/1 requirements will be accepted only if manufactured by firms equipped and competent to undertake high quality welding. In order that firms may be approved for this purpose, it will be necessary for the Surveyors to visit the firm's works for the purpose of inspecting the welding plant, equipment and procedure and to arrange for the carrying out of preliminary tests as stated in 405. Further, in the case of Class 1 approval, arrangements should be made for the survey during construction and testing of a full size welded pressure vessel as stated in 407.

403 The welding plant and equipment are to be suitable for undertaking work of the standard required for Class 1 and Class 2/1 welding and are to be maintained in an efficient working condition. The welding apparatus is to be installed under cover and so arranged that the welding work is carried out in positions free from draughts and adverse weather conditions. The procedure should include the regular systematic supervision of the welding work, and the welding operators are to be subjected by the work's supervisors to periodic tests for quality of workmanship. Records of these tests are to be kept and are to be available for inspection by the Surveyors.

404 The works should be equipped with an efficient testing laboratory which should include apparatus suitable for carrying out tensile, bend and impact tests, micro-examination of specimens and X-ray examination of pressure vessels. The works should also be equipped with a suitable heat-treating furnace having satisfactory means for temperature control.

Alternative arrangements which, in the opinion of the Surveyors, ensure an equally high standard of quality control may be submitted for consideration.



**405** Preliminary tests to demonstrate the quality of the welding work are to be carried out by the firm under the supervision of the Surveyors. The test requirements will be based on the grades of steels, and on the welding process to be used. For approval purposes, the grades of rolled steel plates specified in Q 3 shall be grouped as follows:—

Group 1. Carbon and carbon-manganese steels 360 to 560 N/mm<sup>2</sup> (37 to 57 kgf/mm<sup>2</sup>).

Group 2. Carbon and carbon-manganese steels 510 to 610 N/mm<sup>2</sup> (52 to 62 kgf/mm<sup>2</sup>).

Group 3. Low alloy steels.

Further, the maximum plate thickness which would be approved in pressure vessel construction would depend on the thickness of the test plates used in the preliminary tests; the test plates are, however, to be at least 20 mm thick.

The test plates and the full size pressure vessel mentioned in 407 are to be representative as regards materials and approximate shell thickness of the production vessels for which approval is desired.

The welded seams of the test plates are to be radiographed and the Surveyors are to select portions of the test plates containing the welded joint from which specimens are to be provided for the following tests:—

1. (a) Tensile  
(b) Bend  
(c) Hardness  
(d) Impact  
(e) Fatigue
2. Micrographs at 100 and 300 magnifications, of weld centre, fusion zone and parent plate, for Class 1 application and for steels in groups 2 and 3,
3. Macrograph of full section weld,
4. Chemical analysis of deposited weld metal,
5. Chemical analysis of test plates.

**NOTE.** Where the welding is carried out by an established and approved process, the fatigue tests and micrographs, 1 (e) and 2 above will not in general be required. Further, as an alternative to 5, a guaranteed analysis obtained from the steel makers will be accepted.

**406** If a firm intends to manufacture pressure vessels either of a different group of steel, or by means of a different welding process than used in the preliminary tests on which the original approval was based, further tests will be required to cover the proposed welding procedure. In such cases, full details of the material, plate thickness and welding

process proposed are to be submitted for consideration when the requirements for further preliminary tests will be indicated.

**407** Where firms desire their name to be included in the Society's list of firms recognized by the Committee as experienced manufacturers of Class 1 fusion welded pressure vessels, they should make application at the initial stages of having their works approved. In addition to the preliminary tests, a full size pressure vessel is to be constructed in accordance with the requirements of these Rules for Class 1 fusion welded pressure vessels under the supervision of the Surveyors.

**408** On completion of the inspection and tests, the Surveyor's report, including the results of the preliminary tests and also, for Class 1 approval, the results of the tests of the full size pressure vessel, is to be submitted for the consideration of the Committee. The report should also include the radiographs and particulars of any fusion welded pressure vessels previously constructed by the firm.

#### Routine Tests for Class 1 and Class 2/1 Fusion Welded Pressure Vessels

**409** Two test plates, each of sufficient dimensions to provide one complete set of specimens required by 413, should be prepared for each pressure vessel. They should be attached to the shell plate in such a manner that the edges to be welded are a continuation and simulation of the corresponding edges of the longitudinal joint. The welding process, procedure and technique are to be the same as employed in the welding of the longitudinal joint. Test plates are to be so supported, during welding, that warping is reduced to a minimum.

Alternatively, one test plate may be prepared to provide all the test specimens required by 413 and for retest pieces.

**410** The test plates are to be straightened before being subjected to heat treatment and for this purpose the test plates may be heated to a temperature below that required for the final heat treatment.

**411** Test plates need not be prepared for the circumferential seams, except in cases where a pressure vessel has circumferential seams only, or where the process for welding the circumferential joints is significantly different from that used for the longitudinal joints; when one test plate is to be prepared having a welded joint which so far as possible is a simulation of the circumferential seams. The test plate is to provide all the test specimens required by 413 and for retest pieces.



Where a number of similar vessels are made at the same time it will suffice if test plates are provided for each 30 m of circumferential welded seam.

**412** The test plates are to be cut from the shell plate or plates forming the appropriate seam and before being detached are to be stamped by the Surveyor.

When there is insufficient material available on the shell plates for the provision of test plates, acceptance may be given to test plates cut from another plate provided this plate is from the same cast and in the same heat treatment condition.

The thickness of test plates is to be the same as that of the pressure vessel.

**413** One set of test specimens is to be cut from the test plates as shown in Fig. J 4.1 or Fig. J 4.2 for Class 1 pressure vessels, or as shown in Fig. J 4.3 or Fig. J 4.4 for Class 2/1 pressure vessels. The results of the tests are to comply with the requirements detailed in 415 to 419.

#### Retests

**414** If any of the tests fail, the reason for the failure is to be investigated and two retest specimens are to be prepared and tested. Where two test plates have been prepared, the retests are to be cut from the second test plate. If it can be shown that the failure of the initial test has resulted from local or accidental defect and the retest values are satisfactory, the retest values may be accepted.

#### Tensile Test for all Weld Metal. Specimen No. 1

**415** One all weld metal tensile specimen is to be taken for Class 1 pressure vessels having a shell thickness not exceeding 70 mm and for all Class 2/1 pressure vessels. (The latter pressure vessels are restricted by J 107 to a maximum shell thickness of 38 mm. Where the shell thickness of a Class 1 pressure vessel exceeds 70 mm, two such specimens are to be taken one above the other.

The diameter of the all weld metal test piece at the reduced parallel position is to be not less than 14 mm except in the case of thin plates where the largest practicable diameter should be used. The gauge length of the test piece is to be five times the diameter.

The dimensions of the all weld metal test specimen are shown in Fig. J 4.5(a) and their location when two specimens are used in Fig. J 4.5(b).

The tensile strength of the weld metal is not to be less than the minimum and not more than 145 N/mm<sup>2</sup> (15 kgf/mm<sup>2</sup>) above the minimum specified for the plate.

The percentage elongation A is not to be less than given by:—

$$A = \frac{980 - R}{21,6} \quad \left( A = \frac{100 - R}{2,2} \right)$$

where R is the tensile strength in N/mm<sup>2</sup> (kgf/mm<sup>2</sup>).

In addition, this elongation is not to be less than 80 per cent of the equivalent elongation specified for the plate.

#### Transverse Bend Test. Specimen No. 2

**416** Two bend test specimens of rectangular section are to be cut from the test plate transversely to the weld, one to be bent with the outer surface of the weld in tension, and the other with the inner surface in tension.

The specimens are to have a width equal to 1,5 times the thickness of the specimen and the mid-portion is to coincide with the centre line of the weld. The edges are to be rounded to a radius not exceeding 10 per cent of the thickness.

Where the plate thickness does not exceed 30 mm the thickness of the specimens are to be the full thickness of the plate. Where the plate thickness exceeds 30 mm the specimens, in all cases, are to have a thickness of 30 mm and are to be prepared by discarding metal from the surfaces which will be in compression when the test is applied. See Figs. J 4.6(a) and J 4.6(b).

Where the thickness of the plate permits, the bend specimens may be prepared as shown in Fig. J 4.6(c).

For each specimen the weld reinforcement should be removed by grinding or machining so that the outer and inner surfaces of the weld are flush with the surface of the plate.

The specimen is to be mounted on roller supports with the centre of the weld midway between the supports. A former, with its axis perpendicular to the specimen, is to bend the specimen by pushing it through the clear space between the supports. The diameter of the former and the clear space between the supports will depend on the thickness of the specimens and these dimensions are shown in Table J 4.1 in terms of T, the thickness of the specimen.

After bending there is to be no crack or defect exceeding 1,5 mm measured across the specimen or 3 mm measured along the specimen. Premature failure at the edges of the specimen shall not lead to rejection.

#### Tensile Test for Joint. Specimen No. 3

**417** One reduced section tensile test specimen is to be cut transversely to the weld, or in thick plate, as many tensile test specimens as may be necessary to investigate the tensile strength throughout the whole thickness of the joint. The weld reinforcement should be removed by grinding or machining so that the outer and inner surfaces of the weld



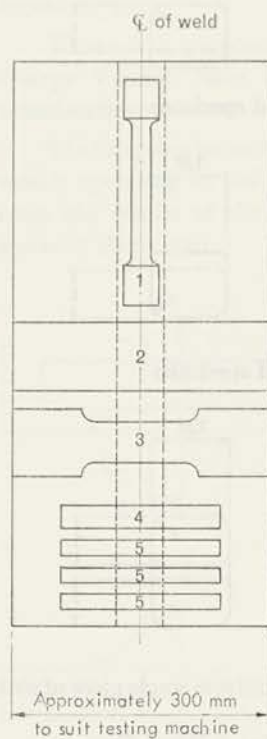


FIG. J 4.1

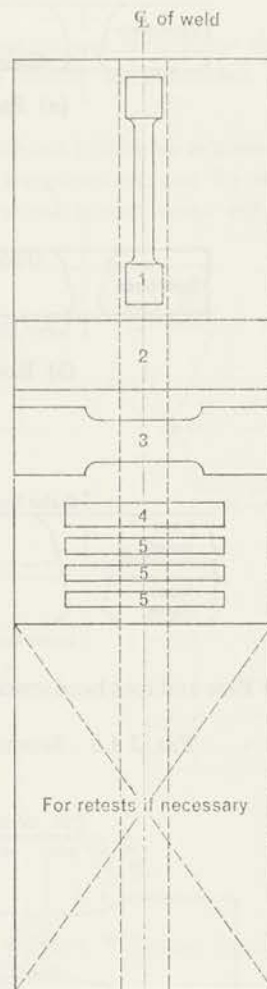


FIG. J 4.2

#### TEST PLATES FOR CLASS 1 VESSELS

1. All weld metal tensile test specimen.
2. Bend test specimens.
3. Tensile test for joint.
4. Macro test specimen.
5. Charpy impact test specimens.

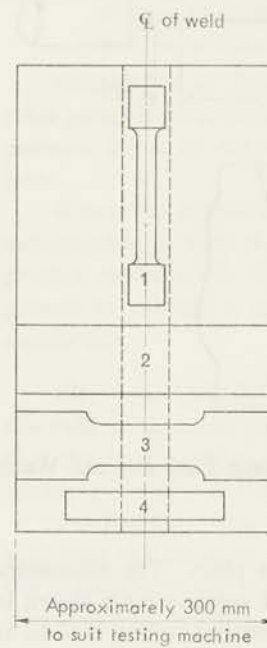


FIG. J 4.3

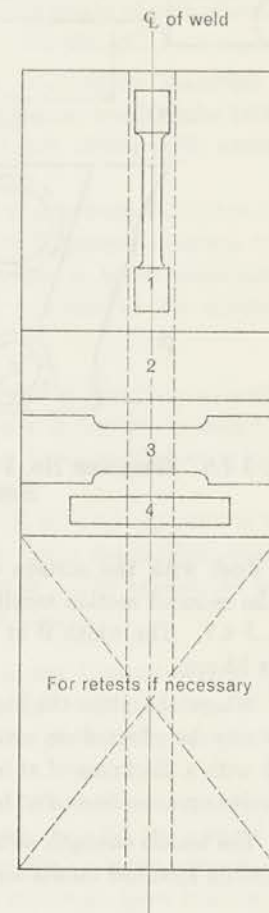


FIG. J 4.4

#### TEST PLATES FOR CLASS 2/1 VESSELS

1. All weld metal tensile test specimen.
2. Bend test specimens.
3. Tensile test for joint.
4. Macro test specimen.

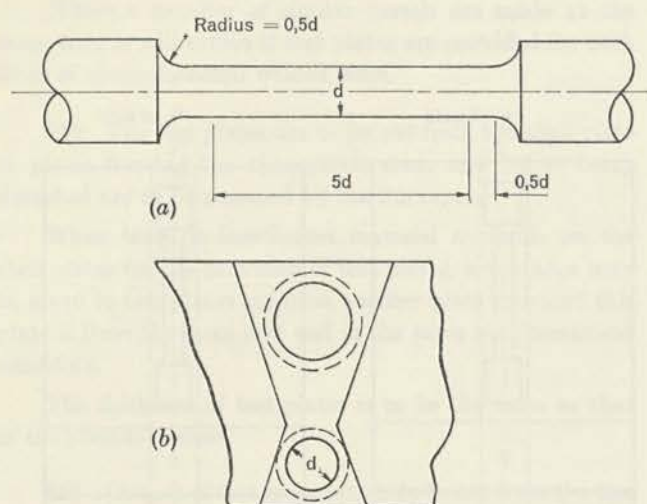


FIG. J 4.5 SPECIMEN NO. 1 TENSILE TEST FOR ALL WELD METAL

are flush with the surface of the plate. The dimensions of the reduced section tensile test specimens are shown in Fig. J 4.7. The width  $B$  at the reduced section is to be at least 25 mm.

Where the plate thickness exceeds 30 mm the tensile test may be effected on several reduced-section specimens each with a thickness of at least 30 mm and a width at the effective cross-section of at least 25 mm.

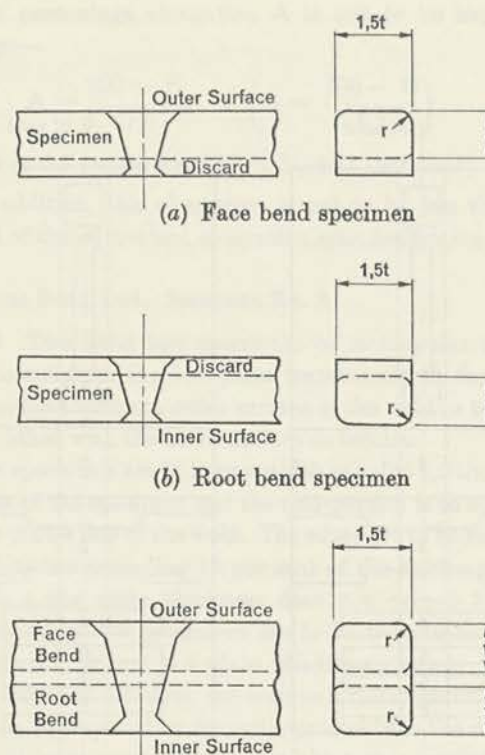
The tensile strength obtained is not to be less than the minimum specified tensile strength for the plate material.

#### Macro Specimen. Specimen No. 4

418 Macro etching of a complete cross-section of the weld including the heat affected zone is to show a satisfactory penetration and an absence of lack of fusion, significant inclusions or other defects.

TABLE J 4.1

MINIMUM SPECIFIED TENSILE STRENGTH OF PLATE		DIAMETER OF FORMER	CLEAR SPACE BETWEEN SUPPORTS
N/mm <sup>2</sup>	(kgf/mm <sup>2</sup> )		
Under 460	(Under 47)	2T	4,2T
460 and under 510	(47 and under 52)	3T	5,2T
510 and not exceeding 620	(52 and not exceeding 63)	4T	6,2T



(c) Face and root bend specimen cut from single piece of plate

FIG. J 4.6 SPECIMEN NO. 2 BEND TEST

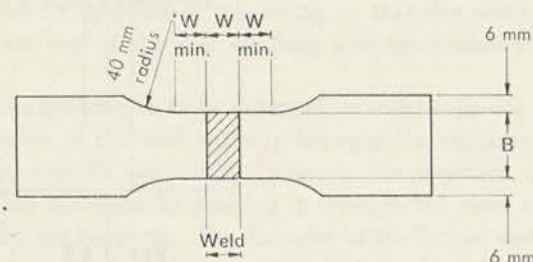


FIG. J 4.7 SPECIMEN NO. 3 TENSILE TEST FOR JOINT

Should there be any doubt as to the condition of the weld as shown by macro etching, the area concerned is to be microscopically examined.

#### Notched Bar Impact Test. Specimen No. 5. Class 1 only

419 Three Charpy V-notch impact test specimens are to be cut transversely to the weld, parallel to the plate surface and at mid-plate thickness. The notch is to be cut at approximately the centre of the weld and the axis of the notch is to be perpendicular to the surface of the plate.

The dimensions of the specimens are as shown in Fig. J 4.8.



The minimum result obtained from the Charpy V-notch test specimens is not to be less than 27 J (2,8 kgf m) when the temperature of the specimen at the time of test does not exceed 50°C.

Where it is proposed to use impact tests other than Charpy V-notch tests, details should be submitted for consideration.

The foregoing impact tests are not applicable to pressure vessels operating at low metal temperatures, and for such cases the results of the weld metal impact tests will be specially considered.

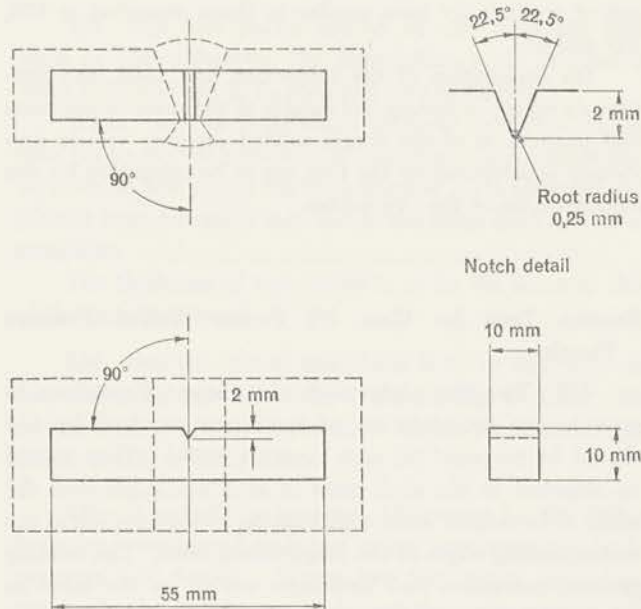


FIG. J 4.8 SPECIMEN NO. 5 CHARPY V-NOTCH IMPACT TEST SPECIMEN

## NON-DESTRUCTIVE EXAMINATION

### Radiographic Examination

**420** The extent of the radiographic examination of the welded seams of Class 1 and Class 2/1 pressure vessels are to be as follows:—

- (a) **Class 1 Pressure Vessels.** All butt welded seams in drums, shells, headers and pipes and tubes over 170 mm outside diameter, together with the test plate or plates, are to be subjected to 100 per cent radiographic examination. For circumferential butt welds in extruded connections, pipes, tubes, headers and other tubular parts 170 mm outside diameter and less, 10 per cent of the total number of welds are to be radiographed. *See also 426.*

- (b) **Class 2/1 Pressure Vessels.** Spot radiographs are to be taken at selected regions of each main seam. The test plate or plates are to be fully radiographed and at least 10 per cent of the length of each main seam is to be so examined. *See also 427.*

Butt welds in furnaces, combustion chambers and other pressure parts for fired pressure vessels under external pressure, are to be subject to spot radiographic examination.

Where the surface finish of any weld which has to be radiographed is such that it will prevent accurate radiographic examination, the surface is to be machined or ground to provide a smooth contour to the Surveyor's satisfaction.

**421** Lead type is to be fixed to the plate adjacent to the weld so that each radiograph is marked in such a way that the corresponding portion of the welded seam can be readily and accurately identified.

The length of weld covered by each exposure is to be such that the metal thickness along the incident beam at the extremity of the exposure is not to exceed the actual thickness by more than 10 per cent.

**422** Image quality indicators (penetrameters) of an approved type are to be placed at each end of each radiograph and on the surface of the plate facing the source of radiation.

Image quality indicators of the step hole type are to be placed alongside the welded seam parallel to its length and are to have a hole in each step of a diameter corresponding to its thickness at that step or are to have some similar device whereby the step thickness can be identified when the radiographic film is examined.

The radiographic technique employed is to be such that the smallest diameter hole visible in the radiograph is not to exceed 3 per cent of the weld thickness for welds not exceeding 50 mm thick, or 2,5 per cent for welds exceeding 50 mm thick. The steps are to bear these proportions to the weld thickness radiographed and the radiographic technique is to be capable of revealing changes of metal thickness of these percentages.

Image quality indicators of the wire type are to be placed across the weld and the smallest diameter wire which can be seen in the radiograph is to have a diameter not greater than 1,5 per cent of the weld thickness, if the weld thickness is between 10 mm and 50 mm and not greater than 1,25 per cent of the weld metal thickness if the thickness exceeds 50 mm up to 200 mm.

The use of gamma rays may be permitted in certain circumstances when details should be submitted for consideration and approval.



423 Radiographs are to be examined by the Surveyors on the original films using a viewing device of suitable illuminating power.

#### Ultrasonic Examination

424 In Class 1 pressure vessels where the plate thickness exceeds 50 mm, ultrasonic examination may be accepted as an alternative to radiographic examination. Such examination is to be effected by an approved operator using an approved technique and an approved recording system. Supplementary examination by radiography may be required at selected locations.

#### Magnetic Crack Detection

425 In Class 1 and Class 2/1 pressure vessels the welds on standpipes, compensating plates, stubs and branches, etc., of ferritic steels, which have not been radiographed are to be magnetically crack detected at the rate of 10 per cent of such welds. This rate may be increased or decreased at the discretion of the Surveyors. For non-magnetic materials dye penetrant examination will be accepted.

#### Repairs to Welded Seams

426 In the case of Class 1 pressure vessels when non-destructive tests show unacceptable defects in the welded seams, the defects are to be repaired and are to be shown by further non-destructive tests to have been eliminated to the Surveyor's satisfaction.

427 In the case of Class 2/1 pressure vessels, when a spot radiograph reveals unacceptable defects in a welded seam, at least two further radiographs are to be made in the length of weld represented by the first radiograph in locations selected by the Surveyor. If these reveal no further unacceptable defects, the defects revealed by the first radiograph are to be repaired and re-radiographed. If the check radiographs reveal unacceptable defects either:—

- (a) the whole length of weld represented is to be cut out and re-welded, then subjected to spot radiography as if it were a new weld, and the original test plates associated with the weld are to be similarly treated, *or*
- (b) the whole length of weld represented is to be radiographed. Unacceptable defects are to be repaired and are to be shown by radiography to have been eliminated.

#### Preliminary Conditions and Tests for Class 2/2 Fusion Welded Pressure Vessels

428 Pressure vessels made in accordance with Class 2/2 requirements will be accepted only if constructed by firms whose works are properly equipped to undertake the welding of pressure vessels of this Class.

The welding plant is to be installed under cover and is to be maintained in an efficient working condition and adequate supervision of the welding work is to be provided.

It will be necessary for the Surveyors to visit the firm's works for the purpose of inspecting the welding plant, equipment and procedure and to arrange for the carrying out of preliminary tests similar to those described in 436, 437 and 438.

On completion of the inspection and tests, the Surveyor's report including the results of the preliminary tests and particulars of the fusion welded pressure vessels previously constructed by the firm are to be submitted for the consideration of the Committee.

#### Routine Tests for Class 2/2 Fusion Welded Pressure Vessels

429 Two test plates each of sufficient dimensions to provide one complete set of specimens required by 434 should be prepared for each pressure vessel. They should be attached to the shell plate in such a manner that the edges to be welded are a continuation and simulation of the corresponding edges of the longitudinal joint. The welding process, procedure and technique are to be the same as employed in the welding of the longitudinal joint. Test plates are to be so supported during welding that warping is reduced to a minimum.

Alternatively, one test plate may be prepared to provide all the test specimens required by 434 and for retest pieces.

430 In cases where a number of Class 2/2 pressure vessels are made concurrently at the same works, and the plate thicknesses do not vary by more than 5 mm, each 37 m of welded seam, longitudinal plus circumferential, may be regarded as equivalent to one pressure vessel, the required number of test specimens being provided accordingly.

In these cases the thickness of the test plates is to be equal to that of the thickest shell plate used in the construction of the pressure vessels.

431 The test plates are to be straightened before being subjected to heat treatment and for this purpose the test plates may be heated to a temperature below that required for the final heat treatment.



432 Test plates need not be prepared for the circumferential seams, except in cases where a pressure vessel has circumferential seams only, or where the process for welding the circumferential joints is significantly different from that used for the longitudinal joints, when one test plate is to be prepared having a welded joint which, so far as possible, is a simulation of the circumferential seams. The test plate is to provide all the test specimens required by 434 and for retest pieces.

Where a number of similar vessels are made at the same time, it will suffice if test plates are provided for each 30 m of circumferential welded seam.

433 The test plates are to be cut from the shell plate or plates forming the appropriate seam and before being detached are to be stamped by the Surveyor.

When there is insufficient material available on the shell plates for the provision of test plates, acceptance may be given to test plates cut from another plate provided this plate is from the same cast and in the same heat treatment condition.

The thickness of test plates is to be the same as that of the pressure vessel.

434 One set of test specimens is to be cut from the test plates as shown in Fig. J 4.9 or Fig. J 4.10. The results of the tests are to comply with the requirements detailed in 436, 437 and 438.

435 If any of the tests fail, the reason for the failure is to be investigated and two retest specimens are to be prepared and tested. Where two test plates have been prepared, the retests are to be cut from the second test plate. If it can be shown that the failure of the initial test has resulted from local or accidental defect and the retest values are satisfactory, the retest values may be accepted.

#### Tensile Test for Joint

436 The shape and preparation of the specimen are to conform to the requirements of 417.

The tensile strength obtained is not to be less than the minimum specified tensile strength for the plate material.

#### Transverse Bend Tests

437 The shape and preparation of the specimens and the procedure for testing are to comply with the requirements of 416 as applicable to the grade of steel permitted by Table J 1.1.

#### Nicked Bend Tests

438 The specimen is to have a slot cut into each side on the centre line of the weld and perpendicular to the plate

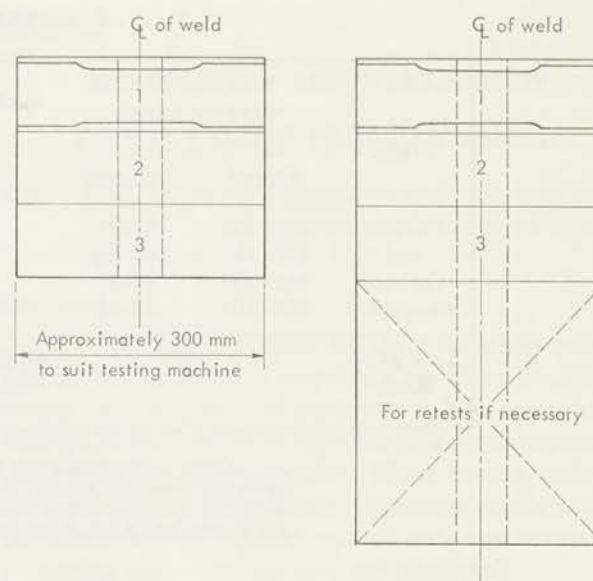


FIG. J 4.9

FIG. J 4.10

#### TEST PLATES FOR CLASS 2/2 VESSELS

1. Tensile test for joint.
2. Bend test specimens.
3. Nicked bend test specimen.

surface. The specimen is then to be broken in the weld and the fracture is to reveal a sound homogeneous weld, substantially free from slag inclusions, porosity and coarse crystallinity.

#### Post-welding Heat Treatment

*Note.* For heat treatment on completion of the forming of shell sections and end plates, see J 504.

439 Depending upon the grade of steel and plate thickness, Class 1, Class 2/1 and Class 2/2 pressure vessels, where indicated in Table J 4.2, are to be efficiently heat treated on completion of the welding of the seams and of all attachments to the shell and ends and before the hydraulic test is carried out.

440 Heat treatment is to be carried out in a properly constructed furnace which is efficiently maintained and has adequate means for temperature control and is fitted with pyrometers which will measure and record the temperature of the furnace charge. The heat treatment is to consist of heating the vessel slowly and uniformly to a suitable stress relieving temperature, soaking for a suitable period, followed by cooling slowly and uniformly in the furnace to a temperature not exceeding 400°C and subsequently cooling

TABLE J 4.2

GRADE OF STEEL	TENSILE RANGE		PLATE THICKNESSES AT AND ABOVE WHICH POST-WELD HEAT TREATMENT IS REQUIRED		
	N/mm <sup>2</sup>	kgf/mm <sup>2</sup>	Class 1	Class 2/1	Class 2/2
Carbon and Carbon-manganese	360-460	37-47	20 mm	See Note below 32 mm 25 mm 20 mm	See Note below 32 mm — —
	410-510	42-52	20 mm		
	460-560	47-57	20 mm		
	510-610	52-62	20 mm		
Low alloy steels	—	—	All thicknesses to be heat treated	—	—

NOTE. The maximum thickness of Class 2/1 and Class 2/2 pressure vessels is limited to 38 mm and heat treatment is not required for carbon and carbon-manganese steels in the tensile range 360-460 N/mm<sup>2</sup> (37-47 kgf/mm<sup>2</sup>).

in a still atmosphere. The temperature and soaking periods are to be selected which will relieve residual stress without undue reduction of the properties of material.

Recommended soaking temperatures and periods are given in Table J 4.3.

In cases where other materials are used for pressure vessel construction, full details of the proposed heat treatment are to be submitted for consideration.

**441** Where pressure vessels are of such dimensions that the whole length cannot be accommodated in the furnace at one time, the pressure vessels may be heated in sections provided sufficient overlap is allowed to ensure the heat treatment of the entire length of the longitudinal seam.

**442** Test plates should be heat treated in the same furnace and at the same time as the pressure vessels which they represent. In special cases, however, it may be permissible to heat treat the test plates separately from the pressure vessels, provided the Surveyor is satisfied with the

means adopted to ensure that the following factors will be the same for the pressure vessels as for their respective test plates:—

Rate of heating,  
Maximum temperature,  
Time held at maximum temperature,  
Conditions of cooling.

**443** Where it is proposed to adopt special methods of heat treatment full particulars are to be submitted for consideration. In such cases it may be necessary to carry out tests to show the effect of the proposed heat treatment.

#### Preliminary Conditions for Class 3 Pressure Vessels

**444** Class 3 pressure vessels will be accepted if constructed by firms whose works are equipped to undertake the welding of pressure vessels of this type. The Surveyors are to be satisfied that the welding equipment, procedure and supervision of the work are adequate and are to test the quality of the welds by preliminary tests.

TABLE J 4.3

TYPE OF STEEL	SOAKING TEMPERATURES	TIME AT TEMPERATURE PER 25 mm OF THICKNESS
Carbon Carbon-manganese	580-620°C	1 hour—min. period 1 hour
1 Cr $\frac{1}{2}$ Mo	620-660°C	1 hour—min. period 2 hours
2 $\frac{1}{4}$ Cr1 Mo	650-690°C	2 hours—min. period 2 hours



Routine weld tests are not required for Class 3 pressure vessels but occasional check tests on the quality of the welding may be carried out at the discretion of the Surveyors.

### Hydraulic Test

445 Boilers and unfired pressure vessels, together with their components, are to withstand the following hydraulic tests without any sign of weakness or defect.

#### 1. Boilers, including Steam Heated Steam Generators.

Having regard to the variation in the types and design of boilers, the hydraulic test may be carried out by either of the methods indicated below:—

- (a) The boiler on completion is to be tested to a pressure of 1.5 times the design pressure, or
- (b) (i) Where construction permits, all components of the boiler are to be tested on completion of the work including heat treatment to 1.5 times the design pressure. In the case of components such as drums or headers, which are to be drilled for tube holes, the test may be made before drilling the tube holes but is to be after the attachment of stand-pipes, stubs and similar fittings and also after heat treatment has been carried out,  
(ii) Provided all the components have been tested as in (i) above, each completed boiler after assembly is to be tested to 1.25 times the design pressure.

Where any of the components have not been tested as in (ii) above, each completed boiler after assembly is to be tested to 1.5 times the design pressure.

#### 2. Unfired Pressure Vessels.

Unfired pressure vessels are to be tested on completion to a pressure,  $P_T$ , which is to be determined by the following formula:—

$$P_T = 1.3 \frac{f_{100}}{f_d} \frac{T}{(T-C)} P$$

but is in no case to exceed  $1.5 \frac{T}{(T-C)} P$

where  $P_T$  = test pressure, in  $N/mm^2$  ( $kgf/cm^2$ ),

$P$  = design pressure, in  $N/mm^2$  ( $kgf/cm^2$ ),

$T$  = nominal thickness of shell as indicated on the plan, in mm,

$C$  = corrosion allowance to be taken as 0.75 mm,

$f_{100}$  = allowable stress at  $100^\circ C$ , in  $N/mm^2$  ( $kgf/cm^2$ ),

$f_d$  = allowable stress at design temperature, in  $N/mm^2$  ( $kgf/cm^2$ ).

## Section 5

### MANUFACTURE AND WORKMANSHIP

#### FUSION WELDED PRESSURE VESSELS

*Note.* The following requirements are applicable to all classes of fusion welded pressure vessels except where otherwise indicated.

#### Electrodes

501 Electrodes intended for use in the construction of pressure vessels are to be stored in a dry place. In order to ensure that the quality of electrodes is being consistently maintained they are to be subjected to a regular system of periodic testing and inspection. Where routine tests are frequently carried out in respect of pressure vessels made in the normal course of production, such tests may be regarded as meeting the requirements of this paragraph.

#### Welding Equipment

502 All welding plant and auxiliary equipment is to be maintained in good working order and adequate means of measuring current are to be provided. In the case of machine welding, means are to be provided for measuring the arc voltage. All electrical plant used in connection with the welding operation is to be adequately earthed.

#### Plate Cutting

503 Plates are to be cut to size and shape by machine flame cutting and/or machining. Where the plate thickness does not exceed 25 mm cold shearing may be used provided that the sheared edge is cut back by machining or chipping for a distance of one quarter of the plate thickness but in no case less than 3 mm.

All plate edges, after cutting and before carrying out further work upon them are to be examined for laminations, and also to ensure that any sheared edges are free from cracks. Visual methods may be supplemented by other techniques at the discretion of the Surveyor.

#### Forming Shell Sections and End Plates

504 Plates for shell sections and end plates are to be formed to the required shape by any process that will not impair the quality of the material. Tests to demonstrate the suitability of a process may be required at the discretion of the Surveyors.

Shell plates are to be formed to the correct contour up to the extreme edges of the plate. So far as possible, hot and cold forming is to be done by machine; forming by hammering with or without local heating is not to be employed.



All plates which have been hot formed or locally heated for forming are to be normalized on completion of this operation. If, however, hot forming is carried out entirely at a temperature within the normalizing range, subsequent heat treatment will not be required for carbon steels. In both instances alloy steels may, in addition, require to be tempered.

All plates which have been cold formed to an internal radius less than 10 times the plate thickness are to be given an appropriate heat treatment.

#### Preparation of Plate Edges and Openings for Welding

505 Welding preparations and openings of the required shapes may be formed by the following methods:—

- (a) Machining, chipping or grinding; chipped surfaces which will not be covered with weld metal are to be ground smooth after chipping.
- (b) Flame cutting.

Special examination will be required for cracks on the cut surfaces and the heat affected zones in flame cut alloy or high carbon steels; preheating may be required in order to ensure satisfactory results when flame cutting.

Any material damaged in the process of cutting plates to size or forming welding grooves is to be removed by machining, grinding or chipping back to sound metal. Surfaces which have been flame cut are to be cut back by machining or grinding so as to remove all burnt metal, notches, slag and scale, but slight discolouration of machine flame cut edges on mild steel is not to be regarded as detrimental. If alloy steels are prepared by flame cutting the surface is to be dressed back by grinding or machining for a distance of at least 1.6 mm unless it has been shown that the material has not been damaged by the cutting process.

506 After edges of the plates have been prepared for welding they are to be carefully examined for flaws, cracks, laminations, slag inclusions or other defects.

507 Care is to be taken to ensure that the weld preparations are correctly profiled.

#### Assembly of Plates for Welding

508 The plates are to be assembled and retained in position for welding by any suitable method; tack welds, where used, are to be removed so that they do not become part of the seam. Correction of irregularities is not to be carried out by hammering.

Where a root gap is specified the edges of butt welds are to be held so that the correct gap is maintained during welding.

Where welded-on bridge pieces or other aids to fabrication are used, care is to be taken that the surfaces of the material are not left in a damaged condition after the attachments have been removed. Any necessary removal of attachments and rectification of scars by welding is to be undertaken before applying post-weld heat treatment.

#### Butt Welds in Plates of Equal Thickness

509 The surfaces of the plates at the longitudinal or circumferential seams are not to be out of alignment with each other at any point by more than 10 per cent of the plate thickness, but in no case is the misalignment to exceed 3 mm for longitudinal seams or 4 mm for circumferential seams.

#### Butt Welds in Plates of Unequal Thickness

510 Where a drum is constructed of plates of different thicknesses (tube plate and wrapper plate), the plates are to be arranged so that their centre lines form a continuous circle. For the longitudinal seams, the thicker plate is to be equally chamfered inside and outside by machining over a circumferential distance not less than twice the difference in the thicknesses so that the two plates are of equal thickness at the position of the longitudinal weld. For the circumferential seam, the thicker plate is to be similarly prepared over the same distance longitudinally.

For the circumferential seam, where the difference in the thicknesses is the same throughout the circumference, the thicker plate is to be reduced in thickness by machining to a taper for a distance not less than four times the offset so that the two plates are of equal thickness at the position of the circumferential weld. A parallel portion may be provided between the end of the taper and the weld edge preparation; alternatively, if so desired, the width of the weld may be included as part of the smooth taper of the thicker plate.

The surfaces of the plates at the longitudinal or circumferential seams are not to be out of alignment with each other at any point by more than 10 per cent of the thickness of the thinner plate, but in no case is the misalignment to exceed 3 mm for longitudinal seams or 4 mm for circumferential seams.

#### Plates Welded Prior to Forming

511 Seams in plates may be welded prior to forming provided on completion of forming and subsequent heat treatment they meet the specified mechanical test requirements and that they are examined radiographically throughout their length after forming (*see, however, J 424*). After forming, the surfaces of such seams in alloy steel parts, also carbon steel parts over 25 mm in thickness, are to be



ground smooth and inspected for cracks by magnetic crack detection, dye penetrants or other means at the discretion of the Surveyor.

#### Attachments and Fittings

512 All lugs, brackets, branches, manhole frames and reinforcements around openings and other members are to conform to the shape of the surface to which they are attached.

The attachment by welding of such fittings to the main pressure shell after post-weld heat treatment is not permitted, except where the material involved is mild steel when welding will only be permitted provided it is necessitated by the method of construction being employed and prior approval of the Surveyor must be obtained before any welding is carried out. In no circumstances is any welding to be done after heat treatment on vessels made of carbon or carbon-manganese steel with tensile strength exceeding 510 N/mm<sup>2</sup> (52 kgf/mm<sup>2</sup>) or of alloy steel.

When the fittings referred to above (*see also J 312*), together with flats and other attachments for supporting internal and external components, are welded to the main pressure shell, the welding is to be of comparable standard to that required for the vessel and the material used is to be of compatible composition.

The finish of all welds attaching pressure parts and non-pressure parts to the main pressure shell is to be such as to permit satisfactory examination of the welds. In the case of Class 1 pressure vessels these welds are to be ground smooth, if necessary, to provide a suitable finish for crack detection tests which are to be carried out to the Surveyor's satisfaction on completion of the hydraulic test.

#### Welding of Main Seams

513 When welding with the manual metal arc and submerged arc welding processes, the following requirements are to be applied. When other processes are utilized it may be necessary to modify or amplify these precautions to ensure satisfactory workmanship.

- (a) All surfaces to be welded are to be thoroughly cleaned of scale, rust, oil or other foreign matter down to a clean surface for a distance of at least 12,5 mm from the welding edge. Welding grooves are to be similarly cleaned.
- (b) Unless otherwise approved seams are to be welded from both sides of the plate. When manual arc welding is employed, the metal at the bottom of the first side is to be removed by grinding, chipping, machining or other approved methods so as to provide clean sound metal on which to deposit the subsequent welds.

The welding procedure for a butt joint welded from one side of the plate is to provide complete fusion. Special care is to be taken to ensure that the root is properly fused and that distortion due to the contraction of the weld metal is minimized.

Backing strips, if used, are to be of the same nominal composition as the plates to be welded and where practicable are to be removed and the surface dressed smooth by grinding prior to radiography.

The roots of butt joints and seams welded from one side of the plate are to be dressed smooth by grinding and before radiographic examination. The dressed surfaces are to be examined for root defects.

- (c) Each run of weld metal is to be thoroughly cleaned and all slag removed before the next run is deposited.
- (d) After welding has been stopped for any reason, care is to be taken in restarting to ensure that the previously deposited weld metal is thoroughly clean and free from slag, and that there is proper penetration into the plates and the previously deposited weld metal.
- (e) Welding is to be carried out in the downhand horizontal position. In the case of circumferential seams means are to be adopted to ensure compliance with this requirement.
- (f) Fillet welds are to be made so as to ensure proper fusion and penetration of the weld metal at the root of the fillet.
- (g) Not less than two runs of metal are to be deposited at each weld affixing branch pipes, flanges and seatings.
- (h) The arc is to be struck only on those parts of the parent metal where the weld metal is to be applied or of the welding metal already deposited.
- (i) Preheating is to be employed when necessitated by the joint restraint, thickness of the plate, and composition of the material to be welded.
- (k) On completion of the welding, the seams are to be thoroughly examined before being dressed or machined. Parts showing evidence of blow-holes, slag inclusions, unsatisfactory penetration, porosity, or any other defect are to be cut out and rewelded, and undercutting made good.

The outer surfaces of the welds may be flush with the surfaces of the plates joined, but no objection will be raised if the total thickness at the centre of the weld is greater than the thickness of the plates, provided the change of section is gradual.



- (l) In cases where it is proposed to adopt fusion welding processes in which it may not be possible to comply fully with the foregoing requirements regarding technique, full particulars are to be submitted for consideration.

#### Tolerances for Cylindrical Shells

514 The shell sections of completed vessels are to be circular within the limits defined in 516. Measurements are to be made to the surface of the parent plate and not to a weld, fitting or other raised part.

Shell sections are to be measured for out-of-roundness either when laid flat on their sides or when set up on end. When the shell sections are checked whilst lying on their sides, each measurement for diameter is to be repeated after turning the shell through 90° about its longitudinal axis. The two measurements for each diameter are to be averaged and the amount of out-of-round calculated from the average values so determined.

There are to be no flats or peaks at welded seams and any local departure from circularity is to be gradual.

515 The external circumference of the completed shell

is not to depart from the calculated circumference (based upon nominal inside diameter and the actual plate thickness) by more than the amounts given in Table J 5.1.

TABLE J 5.1

OUTSIDE DIAMETER (NOMINAL INSIDE DIAMETER PLUS TWICE ACTUAL PLATE THICKNESS)	CIRCUMFERENTIAL TOLERANCE
300 mm up to and including 600 mm	± 5 mm
Over 600 mm	± 0,25 per cent

516 In assessing the out-of-roundness of pressure vessels, the difference between the maximum and minimum internal diameters measured at one cross-section is not to exceed the amount given in Table J 5.2.

The profile, measured on the inside or outside of the shell by means of a gauge of the designed form of the shell and having a length equal to one quarter of the internal diameter of the vessel, is not to depart from the designed form by more than the amount given in Table J 5.2. (This amount corresponds to  $x$  in Fig. J 5.1.)

TABLE J 5.2

NOMINAL INTERNAL DIAMETER OF VESSEL		DIFFERENCE BETWEEN MAX. AND MIN. DIAMETERS	MAXIMUM DEPARTURE FROM DESIGNED FORM
Over	Up to and including		mm
—	300 mm	1,0 per cent of internal diameter	1,2
300 mm	460 mm		1,6
460 mm	600 mm		2,4
600 mm	900 mm		3,2
900 mm	1220 mm		4,0
1220 mm	1520 mm		4,8
1520 mm	1900 mm		5,6
1900 mm	2300 mm	19 mm	6,4
2300 mm	2670 mm		7,2
2670 mm	3950 mm	19 mm 0,4 per cent of vessel internal diameter	8,0
3950 mm	4650 mm		0,2 per cent of vessel diameter
4650 mm			



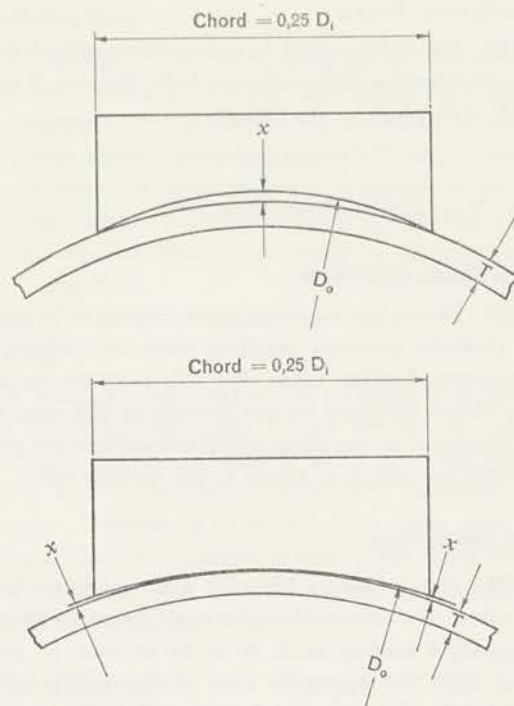


FIG. J 5.1 TOLERANCES FOR CYLINDRICAL SHELLS

## Section 6

### MOUNTINGS AND FITTINGS

#### MOUNTINGS AND FITTINGS FOR CYLINDRICAL AND VERTICAL BOILERS AND UNFIRED STEAM GENERATORS

##### General

**601** Valves over 38 mm diameter are to be fitted with outside screws and the covers are to be secured by bolts or studs. All valves are to be arranged to be shut with a right-hand (clockwise) motion of the wheels.

**602** All valves and cocks connected to the boiler are to be such that it is seen without difficulty whether they are open or shut. Where boiler mountings are secured by studs, the studs are to have a full thread holding in the plate for a length of at least one diameter. If the stud hole penetrates the whole thickness of the plate the stud is to be screwed right through the plate and is to be fitted with a nut inside the boiler. Where bolts are used for securing mountings they are to be screwed right through the plate with their heads inside the boiler.

**603** Where a superheater is fitted which can be shut off from the boiler it is to be provided with a separate safety valve fitted with easing gear. The valve as regards construction is to comply with the regulations for ordinary safety valves, but the easing gear may be fitted to be workable from the stokehold only. The superheater is also to be fitted with a drain valve or cock to free it from water when necessary.

**604** Safety valve chests and other boiler and superheater mountings subjected to pressures exceeding 1.03 N/mm<sup>2</sup> (10.5 kgf/cm<sup>2</sup>) or to steam temperatures exceeding 218°C, and boiler blow down fittings, are to be made of steel or other approved material.

##### Safety Valves

**605** Boilers and unfired steam generators are to be fitted with not less than two safety valves, each having a minimum diameter of 38 mm, but those having a total heating surface of less than 9.3 m<sup>2</sup> may have one valve not less than 50 mm diameter.

**606** The valves, spindles, springs and compression screws are to be so encased and locked that the safety valves and pilot valves, after setting to the working pressure, cannot be tampered with or overloaded in service; the spring casing of superheater safety valves should be ventilated or other arrangement provided to protect the springs from excessive temperature.

Valves are to be so designed that in the event of fracture of springs they cannot lift out of their seats. For safety valves operating at pressures below 1.72 N/mm<sup>2</sup> (17.5 kgf/cm<sup>2</sup>) it should, in general, be possible for the valves to be turned round on their seats by hand.

Easing gear is to be provided for lifting the safety valves and is to be operable by mechanical means at a safe position from the boiler or engine room platforms.

Safety valves are to be made with working parts having ample clearances to ensure complete freedom of movement. Valve seats are to be effectively secured in position. Any adjusting devices which control discharge capacity are to be positively secured so that the adjustment will not be affected when the safety valves are dismantled at surveys.

**607** All the safety valves of each boiler and unfired steam generator may be fitted in one chest, which is to be separate from any other valve chest and is to be connected directly to the shell by a strong and stiff neck, the passage through which is not to be of less cross-sectional area than the aggregate area of the safety valves in the chest in the case of full lift valves and one-half of that area in the case of other valves. For the meaning of aggregate area, see 608.



Each safety valve chest is to be drained by a pipe fitted to the lowest part and led with a continuous fall to the bilge or to a tank, clear of the boilers. No valves or cocks are to be fitted to these drain pipes. It is recommended that the bore of the drain pipes be not less than 19 mm.

#### SATURATED STEAM

**608** The minimum aggregate area of the orifices through the seatings of the safety valves on each boiler and unfired steam generator is to be found by the following formula:—

$$A = \frac{9,81 E}{C (P + 0,103)} \quad \left( A = \frac{100 E}{C (P + 1,05)} \right)$$

where  $A$  = for ordinary, high lift or improved high lift safety valves, the aggregate area in mm<sup>2</sup> of the orifices through the seatings of the valves, neglecting the area of guides and other obstructions,

= for full lift safety valves, the net aggregate area in mm<sup>2</sup> through the seats after deducting the area of the guides or other obstructions when the valves are fully lifted,

$P$  = design pressure, in N/mm<sup>2</sup> (kgf/cm<sup>2</sup>) gauge,

$E$  = designed evaporation in kg/hour. In no case is the designed evaporation to be based on less than 29 kg/m<sup>2</sup>hour of heating surface for coal or oil fired boilers and 14,5 kg/m<sup>2</sup>hour for exhaust gas heated boilers.

$C$  = 4,8 for valves of ordinary type having a minimum lift of  $D/24$ ,  
7,2 for valves of high lift type, having a minimum lift of  $D/16$ ,  
9,6 for valves of improved high lift type having a minimum lift of  $D/12$ ,  
19,2 for valves of full lift type having a minimum lift of  $D/4$ ,

$D$  = bore of valve seat, in mm.

When the discharge capacity of a safety valve of approved design has been established by type tests, carried out in the presence of the Surveyors or by an independent authority recognized by the Society, on valves representative of the range of sizes and pressures intended for marine application, consideration will be given to the use of a higher constant than  $C = 19,2$  based on 90 per cent of the measured capacity up to a maximum of  $C = 45$  for full lift safety valves.

#### SUPERHEATED STEAM

**609** For valves which have to pass superheated steam, the aggregate area of the valves is to be the area  $A$  required by 608, multiplied by the factor:—

$$1 + 0,0018 t$$

where  $t$  = degree of superheat (°C).

#### Unfired Steam Generators

**610** Steam heated steam generators are to be protected from excessive pressure resulting from any failure of the high pressure heating tubes. For this purpose, the area of safety valves obtained by the formula in 608 may require to be increased unless other protective devices are provided to control the supply of steam to the heating tubes.

#### Waste Steam Pipes

**611** For ordinary, high lift and improved high lift type valves, the cross-sectional area of the waste steam pipe and passages leading to it, is to be at least 10 per cent greater than the aggregate area of the safety valves as calculated by the foregoing formulæ. For other valves the cross-sectional area of the waste steam pipe and passages is not to be less than 0,1  $C$  times the aggregate valve area.

The cross-sectional area of the main waste steam pipe is not to be less than the combined cross-sectional areas of the branch waste steam pipes leading thereto from the boiler safety valves.

Waste steam pipes from boilers and unfired steam generators are to be led to the atmosphere and are to be adequately supported and provided with suitable expansion joints, bends or other means to relieve the safety valve chests of undue loading.

The scantlings of waste steam pipes and silencers are to be suitable for the maximum pressure to which the pipes may be subjected in service and not less than 0,25 times the pressure to which the valves are to be set.

Silencers fitted to waste steam pipes are to be so designed that the clear area through the baffle plates is not less than that required for the pipes.

The safety valves of each exhaust gas heated economizer and each exhaust gas heated boiler which may be used as an economizer are to be provided with entirely separate waste steam pipes.

External drains and exhaust steam vents to atmosphere are not to be led to waste steam pipes.

It is recommended that a scale trap and means for cleaning be provided at the base of each waste steam pipe to the Surveyors' satisfaction.



**Accumulation Tests**

**612** All safety valves are to be set under steam to a pressure not greater than 3 per cent above the approved design pressure of the boiler. During a test of 15 minutes with the stop valves closed and under full firing conditions the accumulation of pressure is not to exceed 10 per cent of the design pressure. During this test no more feed water should be supplied than is necessary to maintain a safe working water level.

**Stop Valves**

**613** One main stop valve is to be fitted to each boiler secured direct to the shell. There are to be as few auxiliary stop valves as possible so as to avoid piercing the boiler shell more than is absolutely necessary. The arrangement, however, is to be such that where more than one boiler is fitted it is possible to supply the steam whistle, the steam steering gear, and the electric light machinery from at least two boilers.

**Water Level Indicators**

**614** Every boiler is to be fitted with at least two independent means of indicating the water level in it, one of which is to be a glass gauge. The other means is to be either an additional glass gauge or an approved equivalent device.

On double-ended boilers, the above two water level indicators are to be fitted at each end, one indicator being positioned on each side.

On single-ended boilers, the water level indicators are also to be fitted one on each side of the boiler.

**615** A set of not less than two test cocks will be accepted as the approved equivalent device mentioned in 614, for boilers having a design pressure less than 0,82 N/mm<sup>2</sup> (8,4 kgf/cm<sup>2</sup>) or an internal diameter less than 1,83 m.

The test cocks are to be fitted, where practicable, direct to the boiler plating.

**616** The water gauges are to be readily accessible and placed so that the water level is clearly visible.

The lowest visible part of the glass of the water gauge and the lower test cock, where test cocks are fitted, are to be situated at the lowest safe working water level.

**617** The level of the highest part of the effective heating surfaces, e.g. combustion chamber top of a horizontal boiler and the furnace crown of a vertical boiler, is to be clearly marked in a position adjacent to the glass water gauge.

**618** The cocks of all water gauges are to be accessible from positions free from danger in the event of the glass breaking.

**619** If the water gauges are not fitted directly to the shell of the boiler but to stand pillars or columns, it is desirable that these pillars or columns should be bolted directly to the shell of the boiler. If they are connected to the boiler by means of pipes, the pipes are to be fitted with terminal cocks, not valves, secured direct to the boiler shell. For boilers exceeding 3 m in diameter the pillars are not to be less than 63 mm and the connecting pipes not less than 38 mm internal diameter. For boilers exceeding 2,3 m but not exceeding 3 m in diameter the pillars are not to be less than 50 mm and the pipes not less than 32 mm internal diameter, and for boilers 2,3 m in diameter and under, the pillars are not to be less than 45 mm and the pipes not less than 25 mm internal diameter. The upper ends of the connecting pipes are to be so arranged that there is no pocket or bend where an accumulation of water from the condensation of the steam can lodge. They should not pass through the uptake if they can be otherwise arranged. If, however, this condition cannot be complied with, they may pass through it by means of a passage at least 50 mm clear of the pipe all round, open for ventilation.

**Low Water Level Fuel Shut-off and Alarm**

**620** Each oil fired boiler is to be fitted with a system of water level detection which is to be independent of any other mounting and which will operate audible and visible alarms and shut off automatically the oil supply to the burners when the water level falls to a predetermined low level.

**Feed Check Valves**

**621** Two feed check valves, connected to separate feed lines, are to be provided for all main and auxiliary boilers which are required for essential services with the exception of boilers in which steam is generated exclusively by exhaust gas or steam, where one feed check valve will be accepted. See E 701.

The feed check valves are to be attached, wherever practicable, direct to the boiler but where the arrangements necessitate the use of standpipes between the boiler and the check valves, these pipes are to be of steel or other approved material.

For boiler feed water systems, see E 7.

**Pressure Gauges**

**622** Each boiler is to be provided with a separate steam pressure gauge. Double-ended boilers are to be provided with a pressure gauge at each end. The gauges are to be placed where they are easily seen.



**Blow-down and Scum Valves**

**623** Each boiler is to be fitted with at least one blow-down valve secured direct to the lower part of the boiler.

Where it is not practicable to attach the blow-down valve direct to water tube boilers, the valve may be placed immediately outside the boiler casing with a steel pipe of substantial thickness fitted between the boiler and valve. The pipe and valve are to be suitably supported and any pipe which may be exposed to direct heat from the furnace is to be adequately protected.

The blow-down valve and its connections to the sea need not be more than 38 mm and is not to be less than 19 mm in diameter. For cylindrical boilers the size of the valve in mm may be generally 0,0085 times the diameter of the boiler in mm.

Vertical boilers are to be fitted with a blow-down valve or cock.

**624** Blow-down valves and scum valves (where these latter are fitted) of two or more boilers may be connected to one common discharge, but where thus arranged there are to be screw-down non-return valves fitted for each boiler to prevent the possibility of the contents of one boiler passing to another.

For blow-down valve or cock on ship's side and attachments, see E 267 to E 270.

**Salinometer Valve or Cock**

**625** Each boiler is to be provided with a salinometer valve or cock secured direct to the boiler in a convenient position. The valve or cock is not to be on the water gauge standpipe.

**Hydraulic Tests**

**626** All boiler mountings are to be subjected to a hydraulic test of twice the design pressure with the exception of feed check valves which are to be tested to 2,5 times the design pressure. The test pressures need not, however, be more than 6,86 N/mm<sup>2</sup> (70 kgf/cm<sup>2</sup>) above the design pressure.

## MOUNTINGS AND FITTINGS FOR WATER TUBE BOILERS

**General**

**627** Mountings and fittings not mentioned in 628 to 638 are to be in accordance with the requirements in 601 to 625.

**Safety Valves**

**628** Water tube boilers are to be fitted with not less than two safety valves of area and design in general accordance with the requirements of 605 to 609, except that the minimum diameter of high discharge type valves may be 25 mm or equivalent free area.

Each saturated steam drum and each superheater are to be provided with at least one safety valve.

Where the superheater forms an integral part of the boiler the relieving capacity of the superheater safety valve(s), based on the reduced pressure at the superheater outlet, may be included as part of the total relieving capacity required for the boiler. As some National Authorities limit the proportion of the superheater safety valve relieving capacity which may be credited towards the total capacity required for the boiler, builders should give attention to any relevant statutory requirements of the National Authority of the country in which the ship is to be registered.

The boiler and superheater safety valves are to be so disposed and proportioned between saturated steam drum and superheater outlet that the superheater will be protected from overheating under all service conditions, including an emergency stop of the ship at full power.

Where it is proposed to fit full bore safety valves operated by independent pilot valves, the arrangements are to be submitted for consideration. The pipes connecting pilot valves and main valves are to be of ample bore and wall thickness to minimize the possibility of obstruction and damage.

Where it is impracticable to attach safety valves directly to the superheater the valves are to be located as near as possible thereto and fitted to a branch piece connected to the superheater outlet pipe.

In high temperature installations the drains from safety valves are to be led to a tank or other place where high temperature steam can be safely discharged.

**Waste Steam Pipes**

**629** The waste steam pipe and passages leading to it from the safety valves are to be in general accordance with the requirements of 611.

In installations operating with a high degree of superheat, consideration is to be given to the high temperatures which waste steam pipes, silencers and surrounding spaces will attain when the superheater safety valves are blowing during accumulation tests and in service; adequate protection against heat effects is to be provided to the Surveyor's



satisfaction. Waste steam pipes are to be led well clear of electric cables and any parts or structures sensitive to heat or likely to distort; the pipes are to be insulated where necessary. In these installations each boiler should have a separate waste steam pipe system to atmosphere with supporting and expansion arrangements such that no direct loading is imposed on the safety valve chests.

#### Safety Valve Settings

**630** All boiler and superheater safety valves are to be set under steam to their respective working pressures which are to be not greater than 3 per cent above the approved design pressure of the boiler. In the setting of superheater safety valves, allowance is to be made for the pressure drop through the superheater so that under discharge conditions the pressure in the boiler will not exceed the approved boiler pressure.

In no case shall the superheater safety valve setting exceed by more than 3 per cent the pressure for which the steam piping and shafting are approved.

#### Accumulation Tests

**631** Tests for accumulation of pressure are to be carried out with the stop valve closed and under full firing conditions for a period not exceeding 7 minutes. The accumulation is not to exceed 10 per cent of the design pressure.

Where accumulation tests might endanger the superheaters, consideration will be given in cases of oil-fired boilers to the omission of these tests, provided that application is made when the boiler plan and sizes of safety valves are submitted for approval, and that the safety valves are of an approved type for which the capacity has been established by test in the presence of the Surveyors or an approved independent authority, or for which the Society is satisfied, by long experience of accumulation tests, that the capacity is adequate.

When it is agreed to waive accumulation tests it will be required that the valve makers provide a certificate for each safety valve, stating its rated capacity at the approved working conditions of the boilers and that the boiler makers provide a certificate for each boiler stating its maximum evaporation.

The safety valves are to be found satisfactory in operation under working conditions during the trials of the machinery on board ship.

#### Stop Valves

**632** Where two or more boilers are connected together, stop valves of self-closing or non-return types are to be fitted.

#### Water Level Indicators

**633** Every boiler is to be fitted with at least two independent means of indicating the water level in it, one of which is to be a glass water gauge.

The other means is to be either an additional glass water gauge or an approved equivalent device other than test cocks, but where a steam and water drum exceeding 3,96 m in length is fitted athwartships, two glass water gauges are to be fitted in suitable positions, one near each end of the drum.

**634** The position of the glass water gauges of boilers in which the tubes are entirely drowned when cold is to be such that water is just showing in the glass when the water level in the steam drum is just above the top of the uppermost tubes when the boiler is cold. In boilers, the tubes of which are not entirely drowned when cold, the glass water gauges are to be placed, to the Surveyor's satisfaction, in the positions which have been found by experience to indicate satisfactorily that the water content is sufficient for safety when the boiler is worked under all service conditions.

#### Low Water Level Fuel Shut-off and Alarm

**635** Each oil fired boiler is to be fitted with two systems of water level detection which are to be independent of each other and of any other mounting on the boiler. Both systems are to operate audible and visible alarms and shut off automatically the oil supply to the burners when the water level falls to a predetermined low level.

Any proposal to depart from these requirements in the case of small auxiliary boilers would be the subject of special consideration.

#### Feed Check Valves and Water Level Regulators

**636** Two feed check valves, connected to separate feed lines, are to be provided for each boiler and are to be attached, wherever practicable, direct to the boiler or to an economizer which forms an integral part of the boiler.

Where, however, the arrangements necessitate the use of a common inlet pipe on the economizer for both main and auxiliary feed systems, this pipe is to be as short as practicable and the arrangement of check valves is to be such that either feed line can be effectively isolated without interruption of the feed water supply to the boiler.

At least one of the feed water systems is to be fitted with an approved feed water regulator whereby the water level in the boilers is controlled automatically. (See E 7 for arrangements and details of boiler feed systems.)

637 The feed check valves are to be fitted with efficient gearing, whereby they can be satisfactorily worked from the stokehold floor, or other convenient position.

638 Standpipes on boilers, for feed inlets, are to be designed with an internal pipe to prevent direct contact between the feed pipe and the boiler shell or end plates with the object of minimizing thermal stresses in these plates.

Similar arrangements are to be provided for desuperheater and other connections where significant temperature differences occur in service.

#### Hydraulic Tests

639 All boiler mountings are to be subjected to a hydraulic test of twice the approved boiler design pressure with the exception of feed check valves and other mountings connected to the main feed system which are to be tested to 2.5 times the approved boiler design pressure, or twice the maximum pressure which can be developed in the feed line in normal service, whichever is the greater.

#### MOUNTINGS AND FITTINGS FOR UNFIRED PRESSURE VESSELS

##### General

640 Each receiver which can be isolated from a safety valve is to be provided with a suitable fusible plug to discharge the contents in case of fire. The melting point of the fusible plug is to be approximately 150°C. *See also F 310.*

Where carbon dioxide gas is used for fire extinguishing, it is recommended that the discharge from the fusible plug be piped to deck.

641 Each receiver is to be fitted with a drain arrangement at its lowest part, permitting oil and water to be blown out.

##### Cross-references

642 For starting air pipe systems and safety fittings, *see H 615.*

For mountings for liquefied petroleum gas vessels, *see the Rules for Ships for Liquefied Gases.*



## APPENDIX

FIRMS RECOGNIZED BY THE COMMITTEE FOR THE MANUFACTURE OF CLASS 1  
FUSION WELDED PRESSURE VESSELS AS AT 5.11.75

NOTE. The Society's Office giving attendance at the Works is shown in brackets.

**United Kingdom**

- Adamson & Hatchett Ltd., Dukinfield, Cheshire.  
(MANCHESTER)
- Adamson, Joseph & Co. Ltd., Hyde, Cheshire.  
(MANCHESTER)
- Aiton & Co. Ltd., Derby. (NOTTINGHAM)
- Babcock & Wilcox (Operations) Ltd., Renfrew. (GLASGOW)
- Balfour, Henry & Co. Ltd., Leven, Fife. (LEITH)
- British Steel Corporation, River Don & Associated Works,  
Sheffield. (SHEFFIELD)
- Brown, John, Engineering (Clydebank) Ltd., Clydebank.  
(GLASGOW)
- Butterfield, W. P. (Engineers) Ltd., P.O. Box No. 38,  
Shipley, Yorks. (LEEDS)
- Cammell Laird & Co. (Shipbuilders & Engineers) Ltd.,  
Birkenhead. (LIVERPOOL)
- Clark, George & N. E. M. Ltd., Hartlepool Works.  
(MIDDLESBROUGH)
- Clarke Chapman, Ltd., Gateshead, Tyne & Wear.  
(NEWCASTLE)
- Clarke Chapman, Ltd., Horseley Piggott Division, Dudley,  
Worcs. (BIRMINGHAM)
- Clarke Chapman, Ltd., Horseley Piggott Division, Tipton.  
(BIRMINGHAM)
- Clarke Chapman, Ltd., International Combustion Div.,  
Sinfin Lane, Derby. (NOTTINGHAM)
- Clarke Chapman, Ltd., Thompson-Cochran Div., Newbie  
Works, Annan, Dumfriesshire. (GLASGOW)
- Clarke Chapman, Ltd., Wolverhampton. (BIRMINGHAM)
- Danks of Netherton, Ltd., Netherton. (BIRMINGHAM)
- Distington Engineering Co., Workington, Cumberland.  
(BARROW)
- Grazebrook, M. & W. Ltd., Dudley, Worcestershire.  
(BIRMINGHAM)
- Harland & Wolff Ltd., Belfast. (BELFAST)
- Head Wrightson Teesdale Ltd., Thornaby-on-Tees.  
(MIDDLESBROUGH)
- Hoval-Farrar Boilers Ltd., Newark. (NOTTINGHAM)
- Jenkins, Robert & Co. Ltd., Rotherham. (SHEFFIELD)
- Marshall & Anderson Ltd., Manse Road, Motherwell.  
(Broomside Works). (GLASGOW)
- Marshall-Fowler, Ltd., Britannia Works, Gainsborough.  
(SCUNTHORPE)
- Motherwell Bridge Engineering, Ltd., Motherwell.  
(GLASGOW)
- Neill, Wm. & Son (St. Helens) Ltd., Bold, St. Helens.  
(LIVERPOOL)
- Newton Chambers Engineering Ltd., Thorncliffe, Nr.  
Sheffield. (SHEFFIELD)
- Robey of Lincoln Ltd., Globe Works, Lincoln.  
(NOTTINGHAM)
- Stephen, Alexander, Engineering, Ltd., Glasgow.  
(GLASGOW)
- Sulzer Brothers (UK) Ltd., Alsing Road, Sheffield.  
(SHEFFIELD)
- Towler & Son, Ltd., London, E.15. (LONDON)
- Vickers Ltd., Barrow Engineering Works, Barrow-in-  
Furness. (BARROW)
- Watson, Robert & Co. (Constructional Engineers) Ltd.,  
Bolton, Lancs. (MANCHESTER)
- Weir Pumps Ltd., Cathcart, Glasgow. (GLASGOW)
- Whessoe Ltd., Darlington. (MIDDLESBROUGH)
- Whessoe Ltd., Stockton Works, Stockton-on-Tees.  
(MIDDLESBROUGH)
- Yarrow & Co. Ltd., Scotstoun, Glasgow. (GLASGOW)

**Australia**

- Bernard-Smith P.D.M. Pty., Ltd., Sydney. (SYDNEY)
- Industrial Engineering Ltd., Steelweld Fabrications Divi-  
sion, Braybrook, Victoria. (MELBOURNE)
- Perry Engineering Co., Ltd., Adelaide, S. Australia.  
(ADELAIDE)

**Australia—continued**

Thompsons-Byron Jackson, Castlemaine, Victoria.  
(MELBOURNE)

Vickers Australia Limited, Vickers Hoskins Division,  
Bassendean, Western Australia. (FREMANTLE)

**Austria**

Vereinigte Österreichische Eisen-und-Stahlwerke AG.,  
Linz an der Donau. (VIENNA)

Wagner-Biro AG., Graz, Styria. (VIENNA)

**Belgium**

S.A. Cockerill-Ougree-Providence, Seraing. (ANTWERP)

**Brazil**

Cia. Brasileira de Caldeiras (CBC), Varginha, Minas Gerais.  
(SAO PAULO)

**Canada**

Babcock & Wilcox Canada Ltd., Coronation Boulevard,  
Cambridge, Ontario. (TORONTO)

Davie Shipbuilding, Ltd., Lauzon, P.Q. (MONTREAL)

Foster Wheeler, Ltd., St. Catharines, Ontario. (TORONTO)

**Czechoslovakia**

Vitkovice Zelazarny a Strojirny Klementa Gottwalda  
Narodni podnik, Ostrava. (VIENNA)

**Denmark**

Aalborg Vaerft A/S, Aalborg. (AALBORG)

**Finland**

Valmet Oy, Rautpohjan tehdas, Jyväskylä. (HELSINKI)  
Oy Wartsila A/B, Jarvenpaa Works, Helsingfors.  
(HELSINKI)

**France**

Ateliers & Chantiers de Bretagne, Nantes. (NANTES)

Chantiers de L'Atlantique, Etablissement Mecanique, St.  
Nazaire. (NANTES)

Construction Metalliques de Provence, Arles. (MARSEILLES)

**Germany**

Blohm & Voss AG., Hamburg. (HAMBURG)

Borsig A.G., Berlin-Tegel. (BERLIN)

Bremer-Vulkan, Schiffbau & Maschinenfabrik, Bremen-  
Vegesack. (BREMEN)

Deutsche Babcock & Wilcox A.G., Oberhausen.

(DUSSELDORF)

Dillinger Huttenwerke, Dillingen/Saar. (SAARBRUCKEN)

Gutehoffnungshutte Sterkrade A.G., Werk Sterkrade, Ober-  
hausen-Sterkrade. (DUSSELDORF)

Howaldtswerke-Deutsche Werft A.G., Hamburg und Kiel,  
Werk Kiel. (KIEL)

Howaldtswerke-Deutsche Werft A.G., Hamburg und Kiel,  
Werk Ross, Hamburg. (HAMBURG)

Klockner-Werke A.G., Werk Osnabruck of Osnabruck.

(HANNOVER)

Koerver & Lersch, Krefeld. (DUSSELDORF)

Krupp, Fried. G.m.b.H., Krupp Maschinenfabriken, Essen.  
(DUSSELDORF)

Mannesmannrohren Werke A.G., Werk Duisburg-Huck-  
ingen. (DUSSELDORF)

Mannesmannrohren Werke G.m.b.H., Mulheim.

(DUSSELDORF)

Maschinenfabrik Augsburg-Nurnberg A.G., Werk Hamburg,  
Hachmannkai, Hamburg. (HAMBURG)

Rheinstahl AG, Maschinenbau-Apparatetechnik, Witten-  
Annen. (DORTMUND)

Rheinstahl A.G., Maschinenbau, Kassel. (HANNOVER)

Rheinstahl AG, Umformtechnik und Bergbautechnik  
of Brackwede. (Westf.). (HANNOVER)

Stahl-und Rohrenwerke Reisholz G.m.b.H., Dusseldorf-  
Reisholz. (DUSSELDORF)

Steinmuller, L. & C., G.m.b.H., Gummersbach/Rhld.

(KOLN)

Thyssen Henrichshutte, 4320 Hattingen/Ruhr.

(DORTMUND)

Weser A.G., Bremen. (BREMEN)

**Holland**

"Breda" N.V. Machinefabrik, v/h Backer & Rueb, Rotter-  
dam. (ROTTERDAM)

Bronswerk Apfa-Apparatenfabriek Utrecht N.V., Utrecht.  
(AMSTERDAM)

Bronswerk B.V., Amersfoort. (AMSTERDAM)

Dok-en Werf-Maatschappij Wilton-Fijenoord N.V., Schie-  
dam. (ROTTERDAM)

Koninklijke Machinefabriek Stork N.V., Hengelo.

(AMSTERDAM)

Kon. Mij. "De Schelde" B.V., Vlissingen. (ROTTERDAM)

Nederlandsche Dok en Scheepsbouw Mij. (AMSTERDAM)

Nederlandsche Electrolasch Mij., Leiden. (ROTTERDAM)

Rotterdam Nuclear B.V., P.O. Box 221, Rotterdam.

(ROTTERDAM)



**India**

ACC-Vickers-Babcock, Ltd., Durgapur. (CALCUTTA)  
 Indian Sugar & General Engineering Corporation, Yamuna-  
 nagar. (YAMUNANAGAR)

**Italy**

Acciaieria & Tubificio di Brescia, Brescia. (BRESCIA)  
 Ansaldo Meccanico Nucleare S.p.A., Stabilimento Mec-  
 canico, Genoa. (GENOA)  
 Belleli, R., Mantova. (FRASSINE) (BRESCIA)  
 Bosco Industrie Meccaniche S.p.A., Terni. (NAPLES)  
 Breda Termomeccanica, Milan. (MILAN)  
 C.I.P.I. S.p.A., Venice, (also known as Guido Sartori  
 S.p.A.). (VENICE)  
 Costruzioni Meccaniche Industriali Genovesi-C.M.I., S.p.A.,  
 Genoa-Fegino. (GENOA)  
 Franco Tosi, S.p.A., Legnano. (MILAN)  
 Macchi & C., Fagnano Olona. (MILAN)  
 Nuovo Pignone, Industrie Meccaniche e Fonderia S.p.A.,  
 Stabilimento di Massa, Apuania. (LA SPEZIA)  
 Terni, S.p.A., Societa per l'Industria e l'Elettricit , Terni.  
 (NAPLES)

**Japan**

Babcock-Hitachi K.K., Kure Works, Kure. (HIROSHIMA)  
 Babcock-Hitachi K.K., Yokohama. (YOKOHAMA)  
 Chiyoda Chemical Engineering & Construction Co. Ltd.,  
 Kawasaki Factory, Kawasaki. (YOKOHAMA)  
 Fuji Electric Co. Ltd., Kawasaki Factory, Kawasaki.  
 (YOKOHAMA)  
 Hitachi Shipbuilding & Eng. Co. Ltd., Innoshima Shipyard,  
 Innoshima. (KOBE)  
 Hitachi Shipbuilding & Eng. Co., Ltd., Maizuru Shipyard,  
 Maizuru. (OSAKA)  
 Hitachi Shipbuilding & Eng. Co., Ltd., Sakurajima Works,  
 Osaka. (KOBE)  
 Ishikawajima-Harima Heavy Industries Co., Ltd., Aioi.  
 (KOBE)  
 Kawasaki Heavy Industries, Ltd., Harima Works. (KOBE)  
 Kawasaki Heavy Industries Ltd., Energy Plant Eng.  
 Division, Chiba Works, Chiba City. (YOKOHAMA)  
 Kawasaki Heavy Industries, Ltd., Kobe. (KOBE)  
 Kobe Steel, Ltd., Okubo Plant, Akashi City. (KOBE)  
 Mitsubishi Heavy Industries, Ltd., Kobe Shipyard &  
 Engine Works, Kobe. (KOBE)  
 Mitsubishi Heavy Industries, Ltd., Hiroshima Shipyard &  
 Engine Works. (HIROSHIMA)

Mitsubishi Heavy Industries, Ltd., Nagasaki Shipyard &  
 Engine Works, Nagasaki. (NAGASAKI)  
 Mitsubishi Heavy Industries, Ltd., Yokohama Shipyard &  
 Engine Works, Yokohama. (YOKOHAMA)  
 Mitsui Shipbuilding & Engineering Co., Ltd., Fujinagata  
 Works, Osaka. (KOBE)  
 Mitsui Shipbuilding & Engineering Co., Ltd., Tamano.  
 (KOBE)  
 Nippon Kokan K.K., Tsurumi Shipyard. (YOKOHAMA)  
 Osaka Boiler Manufacturing Co., Ltd. (KOBE)  
 Sasebo Heavy Industries Co., Ltd., Sasebo. (SASEBO)

**Norway**

Elektrisk Sveinsing A/S, Toyenbekken 34, Oslo. (OSLO)  
 Fredriksstad Mek. Verkstad, Fredrikstad. (OSLO)  
 Kvaerner Brug A/S, Oslo. (OSLO)

**Poland**

Fabryka Kotlow Przemyslowych "Fakop", Sosnowiec.  
 (KATOWICE)  
 Huta Ferrum, Katowice. (GDANSK)  
 Stocznia Gdanska (Gdansk Shipbuilding, Marine Engineer-  
 ing & Boiler Works), Gdansk. (GDANSK)

**South Africa**

Barlows Heavy Engineering, Ltd., Benoni, Transvaal.  
 (VEREENIGING)  
 Thompson, John, Africa (Pty.) Ltd., Bellville, Cape  
 Province. (CAPE TOWN)  
 Vecor Heavy Engineering, Ltd., Duncanville Works,  
 Houtkop Road, Duncanville. (VEREENIGING)

**Spain**

Empresa Nacional Bazan, El Ferrol. (EL FERROL)  
 La Maquinista Terrestre y Maritima S.A., Barcelona.  
 (BARCELONA)  
 Mecanica de la Pena, Urduliz. (BILBAO)  
 S.E. de C. Babcock & Wilcox C.A., Galindo Works, Bilbao.  
 (BILBAO)

**Sweden**

Aktiebolaget Gotaverken, Gothenburg. (GOTHENBURG)  
 Avesta Jernverks A/B, Avesta. (STOCKHOLM)  
 Eriksbergs Mek. Verkstads A/B, Gothenburg.  
 (GOTHENBURG)  
 Karlstads Mek. Werkstad A/B, Karlstad. (GOTHENBURG)

## Chapter J

## LLOYD'S REGISTER OF SHIPPING

### Sweden—continued

Kockums Mek. Verkstads A/B, Malmo. (MALMO)

Motala Verkstad A/B, Motala. (GOTHENBURG)

### Switzerland

Brown, Boveri, Ltd., Baden. (WINTERTHUR)

Sulzer Brothers, Ltd., Winterthur. (WINTERTHUR)

### U.S.A.

Babcock & Wilcox Co., Barberton, Ohio. (CLEVELAND)

Chicago Bridge & Iron Co., Birmingham, Alabama.

(MOBILE)

Combustion Engineering Inc., Chattanooga, Tennessee.

(MOBILE)

Foster Wheeler Energy Corporation, Mountaintop, Pa.

(PHILADELPHIA)

### Yugoslavia

Djuro Djakovic, Slavonski Brod. (RIJEKA)

Energoinvest T.A.T., Sarajevo. (RIJEKA)

Tvornica Parnih Kotlova, Zagreb. (RIJEKA)



## Chapter K

### SPARE GEAR FOR STEAM AND OIL ENGINE MACHINERY INSTALLATIONS

SPARE PARTS FOR THE FOLLOWING ITEMS, SO FAR AS THEY ARE APPLICABLE, ARE TO BE CARRIED. THE SPARE PARTS ARE TO BE REPLACED OR MADE GOOD BY THE OWNERS AS OPPORTUNITY OCCURS.

In the case of ships with multi-engine installations, the spare parts required need only be carried for one engine.

**TABLE K.1 SPARE GEAR FOR SHIPS OTHER THAN TRAWLERS OR FISHING VESSELS**  
(see continuation)

ITEM NO.	ITEM	SPARE PARTS REQUIRED TO BE CARRIED		
		NUMBER REQUIRED		SPARE PARTS
		SHIPS FOR UN-RESTRICTED SERVICE	SHIPS FOR RESTRICTED SERVICE	
<b><u>MAIN PROPELLING MACHINERY</u></b>				
STEAM RECIPROCATING ENGINES <i>(See also item 27)</i>				
1	Connecting Rod Bearings	1	1	Bottom end bearing complete with liners, bolts and nuts.
		1	1	Top end bearing complete with liners, bolts and nuts for one connecting rod.
2	Piston Rings	1 set	1 set	Rings and springs for H.P. piston.
3	Piston Valve Rings	1 set	—	Rings and springs, of each size fitted.
4	Piston Rod Metallic Packing	1	—	Complete set of packing for H.P. piston rod and valve spindle.
5	Poppet Valves	1	—	Valve complete with cage, spindle and bush, of each size, fitted together with rollers and springs.
STEAM TURBINES <i>(See also item 27)</i>				
6	Bearing Bushes	1	—	Complete bearing bush, of each size and type fitted, for the rotor, pinion and gear wheel shafts, for one engine.
7	Turbine Thrust	1 set	1 set	Pads of each size for one face of Michell type thrust, or rings for turbine adjusting block, of each size fitted for one engine. Assorted liners for 1 block where fitted.
8	Turbine Shaft Sealing Rings	1 set	—	Carbon sealing rings, where fitted, with springs, for each size and type of gland, for one engine.
9	Oil Filters	1 set	—	Disposable filter elements of each type and size fitted.
OIL ENGINES <i>(See also item 27)</i>				
10	Main Bearings	1	—	Main bearings or shells for one bearing of each size and type fitted, complete with shims, bolts and nuts.

TABLE K.1 (continued)

ITEM NO.	ITEM	SPARE PARTS REQUIRED TO BE CARRIED		
		NUMBER REQUIRED		SPARE PARTS
		SHIPS FOR UN-RESTRICTED SERVICE	SHIPS FOR RESTRICTED SERVICE	
11	Cylinder Liner	1	—	Cylinder liner, complete with joint rings and gaskets.
12	Cylinder Cover	1	—	Cylinder cover, complete with valves, joint rings and gaskets. For engines without covers, the respective valves for one cylinder unit.
		$\frac{1}{2}$ set	—	Cylinder cover bolts and nuts, for one cylinder.
13	Cylinder Valves	2 sets	1 set	Exhaust valves, complete with casings, seats, springs and other fittings for one cylinder.
		1 set	1 set	Air inlet valves, complete with casings, seats, springs and other fittings for one cylinder.
		1	1	Starting air valve, complete with casing, seat, springs and other fittings.
		1	1	Relief valve, complete.
		1 set*	$\frac{1}{4}$ set	Fuel valves of each size and type fitted, complete with all fittings, for one engine. *NOTE. Engines with three or more fuel valves per cylinder: two fuel valves complete per cylinder and a sufficient number of valve parts excluding the body to provide, with those fitted, a full engine set.
14	Connecting Rod Bearings	1 set	—	Bottom end bearings or shells of each size and type fitted, complete with shims, bolts and nuts, for one cylinder.
		1 set	—	Top end bearings or shells of each size and type fitted, complete with shims, bolts and nuts, for one cylinder.
15	Pistons	1	—	Crosshead type: Piston of each type fitted, complete with piston rod, stuffing box, skirt, rings, studs and nuts.
		1	—	Trunk piston type: Piston of each type fitted, complete with skirt, rings, studs, nuts, gudgeon pin and connecting rod.
16	Piston Rings	1 set	—	Piston rings, for one cylinder.
17	Piston Cooling	1 set	—	Telescopic cooling pipes and fittings or their equivalent, for one cylinder unit.
18	Gear and Chain for Camshaft Drives	1 set	—	Gear wheel drive: Complete wheels for the camshaft drive of one engine.
		6	—	Chain drive: Separate links with pins and rollers of each size and type fitted.
		1 set	—	Bearing bushes of each type fitted.
19	Cylinder Lubricators	1	—	Lubricator complete, of the largest size, with its chain drive or gear wheels.
20	Fuel Injection Pumps	1	—	Fuel pump complete, or, when replacement at sea is practicable, a complete set of working parts for one pump (plunger, sleeve, valves, springs, etc.)
21	Fuel Injection Piping	1	—	High pressure fuel pipe of each size and shape fitted, complete with couplings.



TABLE K.1 (continued)

ITEM NO.	ITEM	SPARE PARTS REQUIRED TO BE CARRIED		
		NUMBER REQUIRED		SPARE PARTS
		SHIPS FOR UN-RESTRICTED SERVICE	SHIPS FOR RESTRICTED SERVICE	
22	Scavenge Blowers (including turbo-chargers)	1 set	—	Rotors, rotor shafts, bearings, nozzle rings and gear wheels or equivalent working parts if of other types. NOTE: The spare parts may be omitted where it has been demonstrated at the Enginebuilder's Works, for an engine of the type concerned, that the engine can be manoeuvred satisfactorily with one blower out of action. The requisite blanking arrangements for running with one blower out of action are to be available on board.
23	Scavenging System	1 set	—	Suction and delivery valves for one pump of each type fitted.
24	Reduction and/or Reverse Gear	1 set	—	Complete bearing bush, of each size fitted in the gear case assembly.
		1 set	—	Roller or ball race, of each size fitted in the gear case assembly.
25	Main Engine Driven Air Compressors	1 set	—	Piston rings of each size fitted.
		$\frac{1}{2}$ set	—	Suction and delivery valves complete of each size fitted.
26	Gaskets and Packings	—	1 set	Special gaskets and packings of each size and type fitted for cylinder covers and cylinder liners for one cylinder.
27	APPLICABLE TO ALL TYPES OF MAIN ENGINES			
	Main Thrust Blocks	1 set	1 set	Pads for one face of Michell type thrust block or
		1	1	Complete white metal thrust shoe of solid ring type or
		1	1	Inner and outer race with rollers where roller thrust bearings are fitted.
ELECTRIC PROPELLING MACHINERY		For items of spare gear to be carried, <i>see</i> M 21.		
<b>AUXILIARY MACHINERY</b>				
Where additional units of adequate capacity are fitted no spare gear is required.				
AUXILIARY OIL ENGINES For each type of engine required for essential services.				
28	Main Bearings	1	—	Main bearings or shells for one bearing of each size and type fitted, complete with shims, bolts and nuts.
29	Cylinder Valves	2 sets	—	Exhaust valves, complete with casings, seats, springs and other fittings for one cylinder.
		1 set	—	Air inlet valves, complete with casings, seats, springs and other fittings for one cylinder.
		1	—	Starting air valve, complete with casing, seat, springs and other fittings.
		1	—	Relief valve, complete.
		$\frac{1}{2}$ set	—	Fuel valves of each size and type fitted, complete, with all fittings, for one engine.

TABLE K.1 (continued)

ITEM NO.	ITEM	SPARE PARTS REQUIRED TO BE CARRIED		
		NUMBER REQUIRED		SPARE PARTS
		SHIPS FOR UN-RESTRICTED SERVICE	SHIPS FOR RESTRICTED SERVICE	
30	Connecting Rod Bearings	1 set	—	Bottom end bearings or shells of each size and type fitted, complete with shims, bolts and nuts, for one cylinder.
		1 set	—	Top end bearings or shells of each type fitted, complete with shims, bolts and nuts, for one cylinder.
		1 set	—	Trunk piston type: gudgeon pin with bush for one cylinder.
31	Piston Rings	1 set	—	Piston rings, for one cylinder.
32	Piston Cooling	1 set	—	Telescopic cooling pipes and fittings or their equivalent, for one cylinder unit.
33	Fuel Injection Pumps	1	—	Fuel pump complete, or, when replacement at sea is practicable, a complete set of working parts for one pump (plunger, sleeve, valve springs, etc.)
34	Fuel Injection Piping	1	—	High pressure fuel pipe of each size and shape fitted, complete with couplings.
35	Gaskets and Packings	1 set	—	Special gaskets and packings of each size and type fitted, for cylinder covers and cylinder liners for one cylinder.
36	AUXILIARY STEAM ENGINES	For each size	of engine required for essential services	
	Connecting Rod Bearings	1	1	Bottom end bearing complete with liners, bolts and nuts.
		1	1	Top end bearing complete with liners, bolts and nuts.
37	Piston Rings	1 set	1 set	Rings.
TURBINES DRIVING ESSENTIAL AUXILIARIES		Spare gear to be the same as for main steam turbines in so far as applicable.		
38	AUXILIARY AIR COMPRESSOR			
	Piston Rings	1 set	1 set	Rings, of each size fitted, for one piston.
39	Valves	$\frac{1}{2}$ set	$\frac{1}{2}$ set	Suction and delivery valves, complete, of each size fitted.
ELECTRICAL EQUIPMENT		For items of spare gear to be carried, see M 21.		
REFRIGERATING INSTALLATIONS IN SHIPS		For items of spare gear to be carried, see N 6.		



TABLE K.1 (conclusion)

ITEM NO.	ITEM	SPARE PARTS REQUIRED TO BE CARRIED		
		NUMBER REQUIRED		SPARE PARTS
		SHIPS FOR UN- RESTRICTED SERVICE	SHIPS FOR RESTRICTED SERVICE	
<b><u>BOILERS</u></b>				
40	MAIN AND AUXILIARY BOILERS (See G 103)  Tube Stoppers or Plugs	20	10	Tube stoppers or plugs, of each size used, for boiler, superheater and economizer tubes.
41	Fire Bars	1 set	$\frac{1}{2}$ set	Fire bars for one boiler, where coal fired.
42	Oil Fuel Burners	1 set	1 set	Oil fuel burners complete, for one boiler.
43	Gauge Glasses	2 sets per boiler	2 sets per boiler	Gauge glasses of round type.
		1 set for every two boilers	1 set for every two boilers	Gauge glasses of flat type.

TABLE K.2 SPARE GEAR FOR TRAWLERS AND FISHING VESSELS (see continuation)

ITEM NO.	ITEM	SPARE PARTS REQUIRED TO BE CARRIED	
		NUMBER REQUIRED	SPARE PARTS
<b>MAIN PROPELLING MACHINERY</b>			
STEAM RECIPROCATING ENGINES ( <i>See also</i> item 11)			
1	Connecting Rod Bearings	1	Bottom end bearing complete with liners, bolts and nuts.
		1	Top end bearing complete with liners, bolts and nuts for one connecting rod.
2	Piston Rings	1 set	Rings and springs for H.P. piston.
OIL ENGINES ( <i>See also</i> item 11)			
3	Valves	2	Exhaust valves complete with valve casings, springs and other fittings.
		1	Air inlet valve complete with valve casing, springs and other fittings.
		1	Starting air valve on cylinder complete with valve casings, springs and other fittings.
		$\frac{1}{2}$ set	Fuel valves, of each size and type used, complete with all fittings, for one engine.
		1	Cylinder relief valve complete.
4	Piston Rings (including rings for piston exhaust valves where used)	1 set	Rings, of each size used, for one cylinder.
5	Piston Cooling Pipes	1 set	Telescopic cooling pipes and fittings or their equivalent, for a cylinder unit.
6	Connecting Rod Bearings	1	Bottom end bearing of each type fitted complete with liners, bolts and nuts.
		1	Gudgeon pin bush, where trunk pistons are used.
7	Valves for Scavenge System	$\frac{1}{2}$ set	Suction and delivery valves, for one engine.
8	Fuel Pumps	1	One pump unit complete where a separate pump is provided for each cylinder, or One complete set of working parts for one pump where several pumps are grouped in one body, plus one body.
9	Main Engine Driven Air Compressor	1 set	Piston rings of each size used.
		$\frac{1}{2}$ set	Suction and delivery valves complete of each size used.
10	Fuel Pipes	1	Length of pipe of the greatest length used, complete with flanges or unions, for the fuel delivery to the cylinders.
APPLICABLE TO ALL TYPES OF MAIN ENGINES			
11	Main Thrust Blocks	1 set	Pads for one face of Michell type thrust block, or
		1	Complete white metal thrust shoe of solid ring type, or
		1	Inner and outer face with rollers where roller bearings are used.
ELECTRIC PROPELLING MACHINERY		For items of spare gear to be carried <i>see</i> M 21.	

Table K.2



TABLE K.2 (continued)

ITEM NO.	ITEM	SPARE PARTS REQUIRED TO BE CARRIED	
		NUMBER REQUIRED	SPARE PARTS
<b>AUXILIARY MACHINERY</b>			
Where additional units of adequate capacity are fitted no spare gear is required.			
<b>AUXILIARY OIL ENGINES</b> For each size of engine required for essential services.			
12	Valves	2	Exhaust valves complete with valve casings, springs and other fittings.
		1	Air inlet valve, complete with valve casing, springs and other fittings.
		1	Starting air valve on cylinder complete with valve casing, springs and other fittings.
		$\frac{1}{4}$ set	Fuel valves of each size used, complete with all fittings, for one engine.
		1	Cylinder relief valve complete.
13	Piston Rings	1 set	Rings of each size used, for one cylinder.
14	Piston Cooling Pipes	1 set	Telescopic cooling pipes and fittings or their equivalent, for a cylinder unit.
15	Connecting Rod Bearings	1	Bottom end bearing of each type fitted complete with liners, bolts and nuts.
		1	Gudgeon pin bush, where trunk pistons are used.
16	Valves for Scavenge System	$\frac{1}{4}$ set	Suction and delivery valves, for one engine.
17	Fuel Pumps	1	One pump unit complete where a separate pump is provided for each cylinder, or One complete set of working parts for one pump where several pumps are grouped in one body, plus one body.
18	Fuel Pipes	1	Length of pipe of the greatest length used, complete with flanges or unions, for the fuel delivery to the cylinders.
<b>AUXILIARY STEAM ENGINES</b> For each size of engine required for essential services.			
19	Connecting Rod Bearings	1	Bottom end bearing complete with liners, bolts and nuts.
		1	Top end bearing complete with liners, bolts and nuts.
20	Piston Rings	1 set	Rings.
<b>AUXILIARY AIR COMPRESSOR</b>			
21	Piston Rings	1 set	Rings, of each size used, for one piston.
22	Valves	$\frac{1}{2}$ set	Suction and delivery valves, complete, of each size used.
<b>ELECTRICAL EQUIPMENT</b>		For items of spare gear to be carried, see M 21.	
<b>REFRIGERATING INSTALLATIONS IN TRAWLERS</b>		For items of spare gear to be carried, see N 6.	

TABLE K.2 (conclusion)

ITEM NO.	ITEM	SPARE PARTS REQUIRED TO BE CARRIED	
		NUMBER REQUIRED	SPARE PARTS
<u>BOILERS</u>			
	MAIN AND AUXILIARY BOILERS (See G 103)		
23	Tube Stoppers or Plugs	10	Tube stoppers or plugs, of each size used, for boiler, superheater and economizer tubes.
24	Oil Fuel Burners	1 set	Oil fuel burners complete, for one boiler.
25	Gauge Glasses	2 sets per boiler	Gauge glasses of round type.
		1 set for every two boilers	Gauge glasses of flat type.



# Chapter L

## CONTROL ENGINEERING EQUIPMENT

### Section 1

#### GENERAL REQUIREMENTS

101 (a) This Chapter applies to both passenger ships and cargo ships, and is in addition to other relevant Sections of the Rules.

(b) Whilst these requirements satisfy the regulations of the *International Convention for the Safety of Life at Sea, 1960*, attention should also be given to any relevant statutory requirements of the National Authority of the country in which the ship is to be registered.

(c) This Chapter states requirements for systems of automatic or remote control which may be used for controlling the machinery contained in 102(b).

The design and installation of other control equipment is to be such that there is no risk of danger due to its failure.

(d) The details of control systems will vary with the type of machinery being controlled and special consideration will be given to each case.

#### Plans

102 (a) Where control systems are applied to essential machinery or equipment as listed in 102(b) plans are to be submitted in triplicate. They are to include or be accompanied by:—

Details of operating medium, i.e. pneumatic, hydraulic or electric, including standby sources of power.

Description and/or block diagram showing method of operation.

Line diagrams of control circuits whether open or closed loop.

List of points monitored.

List of alarm points.

List of control points.

Test facilities provided.

Test schedules.

Maintenance programmes, e.g. whether of modular construction so that repair by replacement is intended.

Spare gear, as recommended by the manufacturer.

(b) Control Systems for which Plans are required:—

Ballast systems for dry cargo ships.

Bilge systems.

Cargo pumping systems for tankers.

Controllable pitch propellers.

Electric generating plant.

Evaporating and distilling systems for use with main steam machinery.

Fire detection systems.

Fire extinguishing systems.

Fuel oil transfer and storage systems.

Main propelling machinery including essential auxiliaries.

Steam raising plant.

(c) Alarm Systems

Details of the overall alarm system linking main control station, bridge area and accommodation are to be submitted.

(d) Control Stations

Details of control stations, including bridge control, are to be submitted.

(e) Standard Systems

Where it is intended to employ a system which has been previously approved it will be sufficient to refer to such previous approval. In such cases additional plans are not required.

Alarm and Control Equipment

103 Major units of equipment are to be surveyed at the manufacturer's works. Examples of such major units are:—

Bridge control consoles.

Boiler control consoles.

Display, alarm and data processing consoles.



The workmanship is to be to the Surveyor's satisfaction and the Surveyor is to be satisfied that the components are suitable for the intended environment.

The Society will issue lists of approved components which have been successfully type tested for environment. A copy of the Society's *Test Requirements for the Type Approval of Control and Electrical Equipment* will be furnished on application. **AMENDED - SEE NOTICE NO. 1.**

Assessment of performance parameters, such as accuracy, rangeability and the like, are to be in accordance with an acceptable National or International Standard.

Components used in control systems should, wherever practicable, be selected from the lists of approved equipment to be issued by the Society.

### Alterations or Additions

**104** When an alteration or addition to the approved system(s) is proposed plans are to be submitted for approval. The alterations or additions are to be carried out under the inspection and to the satisfaction of the Surveyors.

## Section 2

### UNATTENDED MACHINERY SPACES—"UMS"

**NOTATION** (See B 301(c))

#### Essential Safety Features

**201** Where it is proposed to operate the ship with unattended machinery spaces, no matter what period is envisaged, the safety features in 202 to 209 inclusive are to be installed.

#### Bridge Control

**202** (a) Means are to be provided to ensure satisfactory control of propulsion from the bridge.

(b) Instrumentation to indicate the following is to be fitted on the bridge:—

- (i) Propeller speed,
- (ii) Direction of rotation of propeller for a fixed pitch propeller or pitch position for a controllable pitch propeller, **SEE ALSO L. 4.**
- (iii) Where a main propulsion oil engine is started from the bridge, indication that sufficient air pressure is available for manoeuvring the engine.

(c) Means of control, independent of the bridge control system, are to be provided on the bridge to enable the watchkeeper to stop the propulsion machinery in an emergency.

(d) Audible and visual alarms are to operate on the bridge and in the alarm system required by 203 if the power supply to the bridge control system fails.

(e) Two means of communication are to be provided between the bridge and the main control station in the machinery space (*see also* D 2114). One of these means may be the bridge control system; the other is to be independent of the main electrical power supply. **SEE ALSO L 204(b)**

#### Alarm System for Propulsion Machinery and Other Essential Machinery

**203** An alarm system which will provide warning of faults in the essential machinery is to be installed. The system is to satisfy the following requirements:—

(a) Machinery faults are to be indicated at the control station for machinery (*see* L 3).

(b) Engineering personnel is/are made aware that a machinery fault has occurred.

(c) If the bridge navigating officer of the watch is the sole watchkeeper, then in the event of a machinery fault being monitored at the control station for machinery (*see* 204), the alarm system is to be such that this watchkeeper is made aware when:—

(i) a machinery fault has occurred,

(ii) the machinery fault is being attended to,

(iii) the machinery fault has been rectified. Alternatively, the system of communication required by 204(b) may be used for this purpose.

(d) The alarm system should, so far as practicable, be designed with self-monitoring properties.

(e) Failure of power supply to the alarm system is to be indicated.

(f) All alarms are to be both audible and visual. If arrangements are fitted to silence audible alarms they are not to extinguish visual alarms.

(g) If the audible alarm has been silenced and a second fault occurs before the first can be rectified the audible alarm is again to operate. **ACCEPTANCE OF ALARMS AT POSITIONS OUTSIDE THE MACHINERY SPACE SHOULD NOT SILENCE THE AUDIBLE ALARM IN THE MACHINERY SPACE.**



**Control Stations for Machinery** *AMENDED SEE NOTICE No. 1*

204 (a) A system of alarm displays is to be provided which readily ensures identification of faults in the machinery. For example, this may be provided by displays at a main control station or, alternatively, at subsidiary control stations. In the latter case, a master display is to be provided showing which of the subsidiary control stations is indicating a fault condition.

(b) At the main control station (if provided) or close to the subsidiary stations (if fitted) there is to be provided means of communication with the bridge area, the accommodation for engineering personnel and, if necessary, the machinery spaces.

The main control station and any other station from which the main propulsion machinery can be controlled are to be provided with means to indicate which station is in control.

**Fire Detection Alarm System**

205 (a) An automatic fire detection system is to be fitted in the machinery spaces together with an audible and visual alarm system.

(b) A fire detector indicator panel is to be located in the navigating bridge area or in such a position that a fire in the machinery spaces will not render it inoperative. Where the machinery spaces are made up of separate compartments, e.g. generator rooms, purifier rooms, etc., the fire detector indicator panel should be sectionalized.

(c) The audible fire alarm is to have a characteristic tone which distinguishes it from the alarm system required by 203. The audible fire alarm is to be audible on all parts of the navigating bridge and in accommodation areas.

(d) The alarm system should, so far as practicable, be designed with self-monitoring properties.

(e) Failure of power supply to the alarm system is to be indicated.

(f) Detector heads of an approved type are to be located in the machinery spaces so that all potential fire outbreak points are guarded.

(g) The fire detection system is to be capable of being tested.

(h) It is to be demonstrated to the Surveyor's satisfaction that detector heads are located so that air currents will not render the system ineffective at sea and in port.

(j) A drawing showing the location of the fire detector heads and the fire detector indicator panel is to be submitted.

**Fire Prevention**

206 (a) Means are to be provided to prevent leaks from high pressure oil fuel injection pipes for main and auxiliary engines dripping or spraying on to hot surfaces or, if applicable, into turbo-charger inlets. Such leakage preferably should be led to a collector tank(s) fitted in a safe position with an alarm to indicate that leakage is taking place.

(b) Means are to be provided to eliminate the possibility of overflow from daily service oil fuel tanks into the machinery spaces, and to safeguard against overflow of oil from the daily service oil fuel tanks through the air pipe. A suitable alarm may satisfy this latter requirement.

(c) Where oil fuel daily service tanks and oil fuel settling tanks are fitted with heating coils, a high temperature alarm is to be provided.

**Bilge Level Alarm System**

207 (a) An alarm system is to be provided to warn that liquid in the machinery space bilges has reached a predetermined level and is to comply with 203. This level is to be sufficiently low to prevent liquid from overflowing from the bilges on to the tank top. In ships above 2000 gross tons at least two independent systems of level detection are to be provided.

(b) Local or remote controls of any valve serving a sea inlet, a discharge below the waterline or a bilge injection system, should be so sited as to be readily accessible and to allow adequate time for operation in case of influx of water to the space, having regard to the time which could be taken to reach and operate such controls.

(c) Automatic starting of bilge pumps is not generally acceptable for the following reasons:—

- (i) Leakage of liquid, either oil or water, into the bilges may be caused by a fault condition. If the bilge pump starts automatically, discovery of the fault condition may be delayed.
- (ii) Consideration of sea pollution. Attention is drawn to the *International Convention for the Prevention of Pollution of the Sea by Oil, 1954*, and subsequent amendments.

However, arrangements with automatic starting may be considered, provided the Society is satisfied that the above requirements are met.

**Supply of Electric Power**

208 Arrangements are to be provided so that essential lighting in the machinery space is switched on automatically if the normal supply of electric power should fail.



**Local Control of Essential Machinery**

209 Arrangements are to be such that the essential machinery can be operated with the system of bridge control or any automatic controls out of action.

Alternatively, the control systems should have sufficient redundancy so that failure of the control equipment in use does not render essential machinery inoperative.

AMENDED SEE NOTICE No.1.

**Section 3**

**ALARMS AND AUTOMATIC CONTROLS FOR  
PROPULSION AND OTHER ESSENTIAL  
MACHINERY—"UMS" NOTATION**

**General**

301 Machinery for propulsion and other essential services is to be protected by the alarm system required by L 203, and machinery faults are to be identifiable at the main control station for machinery as required by L 204.

The minimum requirements for the alarm systems and automatic stop or shut down of different types of machinery installations are given in 302 to 307.

AMENDED SEE NOTICE No.1

**OIL ENGINES FOR PROPULSION PURPOSES****302 (a) Alarms and Safeguards**

Preferred alarms and safeguards are indicated in (b), (c), (d) and (e) of this paragraph and Table L 3.1.

Alternative arrangements which provide equivalent safeguards could be accepted.

**(b) Automatic Stop for Failure of Lubricating Oil Supply**

In the case of the lubricating oil system, in addition to the alarm indication required by 302 (a), the engine is to be stopped automatically for complete loss of lubricating oil. The circuit employed for this automatic stop is to be additional to the alarm circuit required by 302 (a).

**(c) Crankcase Protection**

Oil mist monitoring is to be provided when arrangements are fitted to override the automatic stop for failure of lubricating oil supply.

**(d) Speed Reduction for Fault Conditions**

Audible and visual alarms are to operate, and indication is to be given on the bridge that the speed of the main engine(s) is to be reduced for the following fault conditions:—

- (i) High scavenge air temperature (fire detection).
- (ii) Oil mist detected in crankcase (if detector fitted).
- (iii) Low piston coolant outlet flow.
- (iv) Low piston coolant pressure; low cylinder coolant pressure, if on separate circuit.

Reduction of speed may be effected by either manual or automatic control.

**(e) Automatic Start of Standby Pumps**

Where the lubricating oil, cooling media and oil fuel booster pumps are not driven by the main engine(s), the standby pump is to start automatically if the discharge pressure from the working pump falls below a predetermined value.

**TABLE L 3.1**

ITEM	ALARM	NOTE
Lubricating oil inlet pressure	Low	Engines (and gearing, if fitted)
Lubricating oil inlet temperature	High	—
Cylinder lubricator flow	Low	One sensor per lubricator unit
Piston coolant inlet pressure	Low	If separate system
Piston coolant outlet temperature	High	Per cylinder
Piston coolant outlet flow	Low	Per cylinder
Cylinder coolant inlet pressure	Low	—
Cylinder coolant outlet temperature	High	Per cylinder
Fuel valve coolant pressure	Low	If separate system
Oil fuel pressure from booster pump	Low	—
Oil fuel temperature or viscosity	High and Low	} Heavy oil only
Scavenge air temperature	High	
Exhaust gas temperature	High	Per cylinder
Starting air pressure	Low	Before engine manoeuvring valve

NOTE. Where "per cylinder" appears in this Table, suitable alarms may be situated on manifold outlets for medium and high speed engines.



### STEAM TURBINE MACHINERY FOR PROPULSION PURPOSES

#### 303 (a) Alarms and Safeguards

Preferred alarms and safeguards are indicated in (b), (c), (d) and (e) of this paragraph and Table L 3.2.

Alternative arrangements which provide equivalent safeguards could be accepted.

#### (b) Automatic Stop for Failure of Lubricating Oil Supply

AMENDED SEE NOTICE No. 1.  
In the case of the lubricating oil system, in addition to alarm indication required by 303 (a), steam is to be shut off automatically from the turbine(s) for complete loss of lubricating oil. The circuit employed for this automatic shut-off is to be additional to the alarm circuit required by 303 (a).

#### (c) Speed Reduction for Fault Conditions

Audible and visual alarms are to operate, and indication is to be given on the bridge, to stop or reduce the speed of the turbine(s) for the following fault conditions:—

- (i) Excessive turbine vibration.
- (ii) Excessive axial movement of turbine rotor.
- (iii) Low vacuum in main condenser.
- (iv) High condensate level in main condenser.

Reduction of speed may be effected by either manual or automatic control.

TABLE L 3.2

ITEM	ALARM
Lubricating oil pressure for turbines and gearing	Low
Lubricating oil temperature for turbines and gearing	High
Bearing temperatures of turbines and gearing	High
Astern turbine temperature	High
Gland steam pressure	{ High and Low
Sea water pressure or flow	Low
Turbine vibration	Excessive
Axial movement of turbine rotor	Excessive
Main condenser vacuum	Low
Main condenser condensate level	High

#### (d) Lubricating Oil Supply

Where electric power is normally used to supply lubricating oil to the turbines and gearing, means are to be provided to safeguard the turbines from possible damage caused by rotation from propeller water torque if the normally connected supply of electric power should fail.

#### (e) Automatic Start of Standby Pumps

The standby pumps for turbine and gearing lubricating oil systems and condensate extraction are to start automatically when the discharge pressure from the working pump falls below a predetermined value. For sea water the auxiliary pump is to start automatically when the sea water pressure (or flow) falls below a predetermined value.

SECOND SUB-PARA ADDED - SEE NOTICE No. 1

### GAS TURBINE MACHINERY FOR PROPULSION PURPOSES

#### 304 (a) Alarms and Safeguards

Details of alarms and safeguards, including automatic start of standby pumps, where fitted, are to be submitted for consideration.

Means are to be provided in the bridge and engine room control systems to prevent excessive torque or other harmful effects. See L 401 and H 927.

#### (b) Automatic Stop Devices

Arrangements are to be provided to automatically stop the turbine for the following fault conditions:—

- (i) Overspeed, see H 926.
- (ii) High exhaust temperature, see H 912.
- (iii) Flame failure.
- (iv) Excessive vibration.
- (v) Failure of lubricating oil pressure. See also H 929.

Alternative arrangements which provide equivalent safeguards could be accepted, see H 930.

### MAIN AND AUXILIARY BOILERS

#### 305 (a) Alarms and Safeguards

Preferred alarms and safeguards are indicated in (b) of this paragraph and Table L 3.3.

Alternative arrangements which provide equivalent safeguards could be accepted.

#### (b) Automatic Start of Standby Pumps

The standby pumps for feed water and oil fuel should start automatically when the discharge pressure from the working pump falls below a predetermined value.

SEE E.303, E701, & E702.

NOTICE No 1.

L 303 - L 305



Amended SEE NOTICE No. 1,

TABLE L 3.3

ITEM	ALARM	NOTE
Water level	Low	Two independent low water level sensors are to be fitted which will operate alarms and automatically shut off oil fuel to burners—see Note 2
Water level	High	—
Steam drum pressure	High and Low	—
Superheated steam temperature	High	—
De-superheated steam temperature	High	—
Feed water forced circulation flow (if fitted)	Low	Oil fuel to burners to be shut off automatically.
Feed water salinity	High	—
Combustion air pressure	Low	Oil fuel to burners to be shut off automatically
Oil fuel pressure	Low	—
Oil fuel temperature or viscosity	High and Low	} Heavy oil only
Oil fuel atomizing steam/air pressure	Low	
Burner flame and ignition	Failure	Each burner to be monitored. Oil fuel to burner(s) to be shut off automatically. Furnace uptakes to be purged automatically before re-ignition

## NOTES

1. For dual evaporation boilers, the primary circuit is to be fitted with two independent low water level detectors which will operate alarms and shut off the oil fuel to the burners automatically.

The secondary circuit is to be fitted with one low water level detector which will operate alarms and shut off the oil fuel to the burners automatically. One high water level alarm should also be fitted which may be operated by the same detector.

2. Only one independent system of low water level detection, alarm and automatic oil fuel shut off need be fitted in the case of small forced circulation or re-circulation coiled water tube "package" type auxiliary boilers.

ELECTRIC GENERATING PLANT—"UMS"  
NOTATION

## 306 (a) Alarms and Safeguards

Preferred alarms and safeguards are indicated in (b) of this paragraph and Table L 3.4.

Alternative arrangements which provide equivalent safeguards could be accepted.

## (b) Automatic Connection of Standby Generator

Where automatic start of the standby generating set with automatic connection to the busbars is provided, automatic closure on to the busbars is to be limited to one attempt, to limit damage to the electrical system in the event of the original power failure being caused by short-circuit.

TABLE L 3.4

ITEM	ALARM	NOTE
GENERATORS		
Voltage	High and Low	} For parallel running, a.c. generators may be satisfied by suitable system design
Frequency	Low	
Operation of load shedding	Warning	see M 615
OIL ENGINES		
Lubricating oil inlet temperature	High	—
Lubricating oil inlet pressure	Low	—
Lubricating oil inlet pressure	Failure	Automatic shut down of engine
Coolant outlet temperature	High	For engines over 220 kW (300 shp)
Coolant outlet temperature	Excessively High	For engines over 220 kW (300 shp) Automatic shut down of engine
Overspeed	—	See H 610
STEAM TURBINES		
Lubricating oil inlet temperature	High	—
Lubricating oil inlet pressure	Low	—
Lubricating oil inlet pressure	Failure	Automatic shut down of turbine
Condenser vacuum	Low	—
Condenser vacuum	Excessively Low	} Automatic shut down of turbine
Axial displacement of rotor	Excessive	
Overspeed	—	See H 828



MISCELLANEOUS ALARMS FOR STEAM AND OIL  
ENGINE MACHINERY

307 Table L 3.5 indicates preferred alarms.

Alternative arrangements which provide equivalent safeguards could be accepted.

TABLE L 3.5

ITEM	ALARM	NOTE
Lubricating oil sumps for oil engines, turbines and gearing	Low level	Propulsion machinery only
Stern tube lubricating oil tanks	Low level	—
Coolant tanks	Low level	—
Daily service oil fuel tanks	High level Low level	One high level alarm may be fitted in a common overflow tank
Sludge tanks	High level	—
Feed water tanks	Low level	Service tank only
Thrust bearing	High Temperature	—
Stern tube bearing (oil lubricated)	High Temperature	—
Operating medium for hydraulic or pneumatic coupling in propulsion system	Low Pressure	—
Pneumatic control pressure	Low Pressure	—
Hydraulic control system	Low Pressure	—

## Section 4

FOR VESSELS  
WITH BRIDGE CONTROL NOTATION  
**CONTROLLABLE PITCH PROPELLERS**

401 The following are preferred alarms. Alternative arrangements which provide equivalent safeguards could be accepted. *AMENDED SEE NOTICE No. 1.*

## (a) Main Propulsion

- (i) A propeller pitch and shaft rpm indicator is to be fitted at each station from which it is possible to control the pitch of the propeller.

- (ii) Means are to be provided to prevent the engine and shafting being subjected to excessive torque due to changes in propeller pitch; alternatively an engine overload indicator may be fitted at each station from which it is possible to control the pitch of the propeller. *AMENDED SEE NOTICE No. 1.*

- (iii) A standby or alternative power source of actuating medium for controlling the pitch of the propeller blades is to be provided.

Automatic start of the standby pump supplying hydraulic power for pitch control is recommended.

- (iv) Audible and visual alarms are to operate for the following:—

Low pressure in hydraulic system.

Low level in hydraulic supply tank.

Failure of power supply to the control system between the bridge and the hydraulic actuator.

High temperature oil at cooler outlet.

## (b) Transverse Thrust Units

- (i) A pitch indicator is to be fitted at each station from which it is possible to control the pitch of the propeller.

- (ii) Audible and visual alarms are to operate for the following:—

Low pressure in hydraulic system.

Low level in hydraulic supply tank.

Failure of power supply to the control system between the bridge and the hydraulic actuator.

Overload on propulsion motor.

- (iii) Means are to be provided on the bridge to stop the propulsion motor.

*NEW TABLES ADDED: - L4.1 & L4.2. SEE NOTICE No. 1.*

## Section 5

## CRITICAL SPEEDS—"UMS" NOTATION

501 Prolonged running in a restricted speed range is to be prevented automatically; alternatively, indication of restricted speed ranges is to be provided at each control station.

Section 6

AMENDED SEE NOTICE No. 1.

~~REQUIREMENTS FOR UNATTENDED MACHINERY SPACES IN TUGS, COASTERS AND OTHER SMALL SHIPS HAVING PROPULSION MACHINERY OF LESS THAN 1470 kW (2000 SHP)—“UMS” NOTATION~~

AMENDED SEE NOTICE No. 1.

601 The requirements of L 2 are to be applied.

In addition, the alarm system is to indicate the following:—

- (a) Failure of control medium for bridge control system.
- (b) Low lubricating oil pressure for main and auxiliary oil engines.
- (c) Low cooling water pressure or high cooling water temperature for main and auxiliary oil engines.
- (d) Boiler flame failure and low water level independently.

NEW TABLE L.6.1 ADDED - SEE NOTICE No. 1.

Section 7**ATTENDED MACHINERY SPACES**

701 Where it is proposed to operate the ship with attended machinery spaces, and control equipment is fitted to the essential machinery, means are to be provided so that such machinery can be operated with any automatic control system(s) out of action.

Section 8**CARGO, BILGE AND BALLAST VALVES WITH REMOTE OR AUTOMATIC CONTROL**

801 Where cargo or ballast valves are operated by remote or automatic control and bilge valves by remote control, the system of control should include the following safety features:—

- (a) Failure of actuator power should not permit a valve to open inadvertently.
- (b) Indication is to be provided at the remote control station for these services that the valve is open or closed.
- (c) Equipment located in places which may be flooded should be capable of operating when submerged.
- (d) A secondary means of operating the valves, which may be manual control, is to be provided. (See E 250.)

NEW SECTION 9 - SEE NOTICE No. 1. TABLE 9.1 ADDED.  
TURBINE DRIVEN CARGO & BALLAST PUMPS IN HAZARDOUS SPACES.

Section 10**TRIALS**

SEE NOTICE No. 1.

1001

Before a new installation, or any alteration or addition to an existing installation, is put into service trials are to be carried out. These trials are in addition to any acceptance tests which may have been carried out at the manufacturers' works and are to be based on the test schedules list called for in L 102.

It will be expected that most of these trials will be carried out before the sea trials of the ship.



# Chapter M

## ELECTRICAL EQUIPMENT AND ELECTRIC PROPELLING MACHINERY

### Section 1

#### GENERAL REQUIREMENTS

101 (a) The requirements of this Chapter apply to passenger ships and cargo ships except where otherwise stated. While these requirements are considered to meet those of the 1960 Safety of Life at Sea Convention, attention must be given to any relevant statutory regulations of the National Authority of the country in which the ship is to be registered. Compliance with the statutory regulations of the National Authority may be accepted as meeting the requirements of the 1960 Safety of Life at Sea Convention.

(b) In passenger ships services essential for safety are to be maintained under emergency conditions and the safety of ship and personnel from electrical hazards is to be assured.

(c) This Chapter states requirements for those features of the electrical installation which are considered essential for the safety of the ship. The design and installation of other equipment is to be such that there is no risk of fire due to its failure. It must, as a minimum, comply with a National or International standard.

(d) The Committee will be prepared to give consideration to special cases or to arrangements which are equivalent to the Rules. Consideration will also be given to the electrical arrangements of small ships and ships to be assigned class notations for restricted or special services.

(e) Electrical installations for propulsion and auxiliary services are to be constructed and installed in accordance with the relevant Sections of this Chapter and are to be inspected and tested by the Surveyors. Compliance with the recommendations of the International Electrotechnical Commission (IEC) Publication 92, *Electrical Installations in Ships*, or with an equivalent National standard, may be accepted as meeting the requirements of this Chapter subject to inspection and testing by the Surveyors.

#### Plans

102 The following plans and particulars are to be submitted in triplicate, for consideration:—

#### PROPULSION EQUIPMENT

Plans of generators, motors and seatings together with diagrams of control gear, cables and circuits, and particulars of voltage, current, power and speed with a key diagram and explanation of the system in relation to the requirements of M 17.

#### ELECTRIC SLIP COUPLINGS

Plans showing the scantlings and construction of the couplings together with diagrams of electrical components, switchgear and control gear.

#### ELECTRICAL EQUIPMENT (other than propulsion equipment)

The arrangement plan and circuit diagram of the switchboard(s). Diagrams of the wiring system including cable sizes, type of insulation, normal working current in the circuits and the capacity, type and make of protective devices. Calculations of short-circuit currents at main busbars, sub-switchboard busbars and the secondary side of transformers are to be submitted. (See M 611)

#### WELDING ON SHAFTS

Where welding is to be applied to shafts of machines for essential services for securing armature arms or spiders, plans showing the construction are to be submitted for consideration.

#### PRIME MOVERS

See G 104.

#### CENTRALIZED, BRIDGE OR AUTOMATIC CONTROLS

See F 105 and Chapter L.

NEW ENTRY - TANKERS (OIL, GAS, CHEMICAL) SEE NOTICE No. 1.

#### Additions or Alterations

103 An addition, temporary or permanent, is not to be made to the approved load of an existing installation until it has been ascertained that the current-carrying capacity and the condition of the existing accessories, conductors and switchgear are adequate for the increased load. (See C 108.)

Plans are to be submitted for approval and the alterations or additions are to be carried out under the inspection and to the satisfaction of the Surveyors.



**Application**

**104** Except where a specific statement is made to the contrary all requirements of this Chapter are applicable to both alternating current and direct current installations.

**105** Direct current equipment is to operate satisfactorily under voltage fluctuations of plus 6 per cent and minus 10 per cent.

Alternating current equipment is to operate satisfactorily under voltage fluctuations of plus 6 per cent and minus 10 per cent at rated frequency and under frequency fluctuations of plus or minus 2,5 per cent at rated voltage.

Contactors and similar equipment are not to drop out at or above 85 per cent rated voltage.

**Ambient Temperatures**

**106** The following cooling air and cooling water temperatures are applicable in ships classed for:—

**(a) UNRESTRICTED SERVICE**

- |                                  |      |
|----------------------------------|------|
| (i) Primary cooling water supply | 30°C |
| (ii) Cooling air temperature     | 45°C |

**(b) RESTRICTED SERVICE (See B 118 to B 122)**

Vessels intended solely for use in northern or southern waters outside the tropical belt.

- |                                  |      |
|----------------------------------|------|
| (i) Primary cooling water supply | 25°C |
| (ii) Cooling air temperature     | 40°C |

**Location and Construction**

**107** Electrical equipment is to be accessibly placed clear of flammable material in well ventilated, adequately lighted spaces in which flammable gases cannot accumulate and where it is not exposed to risk of mechanical injury or damage from water, steam or oil. Where necessarily exposed to such risks the equipment is to be suitably constructed or enclosed. Live parts are to be guarded where necessary.

Insulating materials and insulated windings are to be resistant to tracking, moisture, sea air and oil vapour unless special precautions are taken to protect them.

Equipment is not to remain alive through the control circuits and/or pilot lamps when switched off by the control switch. This does not apply to synchronizing switches and/or plugs.

The operation of all electrical equipment and the lubricating arrangements are to be efficient under such conditions of vibration and shock as arise in normal practice, and with the ship inclined from the normal at any angle up to 15 degrees transversely, when pitching 10 degrees longitudinally and when rolling up to 22,5 degrees from the vertical.

All nuts and screws used in connection with current-carrying parts and working parts are to be effectively locked.

Conductors and equipment are to be placed at such a distance from the magnetic compasses or are to be so disposed that the interfering magnetic field is negligible even when circuits are switched on and off.

Where electric power is used for propulsion, the equipment is to be arranged so that it will operate satisfactorily in the event of partial flooding by bilge water above the tank top up to floor plate level. See E 223 and E 224.

**Earthing**

**108** (a) Non-current-carrying metal parts of electrical equipment are to be effectively earthed. Where earthing connections are necessary they are to be of copper or other approved material and are to be protected against damage and, where necessary, electrolytic action. In general, they are to be equal to the cross section of the current-carrying conductor up to 16 mm<sup>2</sup>. Above this figure they are to be equal to at least half the cross section of the current-carrying conductor with a minimum of 16 mm<sup>2</sup>.

(b) **PORTABLE EQUIPMENT**—Metal frames of all portable electric lamps, tools and similar apparatus supplied as ship's equipment and rated in excess of 55 V are to be earthed through a suitable conductor unless equivalent safety provisions are made such as by double insulation or by an isolating transformer.

*ELECTRICAL EQUIPMENT FOR USE IN EXPLOSIVE GAS ATMOSPHERE*  
~~Flameproof and Intrinsically Safe Equipment~~ *AMENDED SEE NOTICE No. 1.*

**109** Where risk of explosion might otherwise arise, equipment is to be of flameproof or intrinsically safe type.

Where equipment is required to be of flameproof or intrinsically safe type and equipment of suitable type is obtainable which has been type tested and approved by a competent independent Testing Authority, it will be sufficient to furnish a copy of the relevant certificate, provided that there is no departure from the design so tested and approved.

*SUB PARAGRAPHS ADDED SEE NOTICE No. 3.*  
**NOTE.**

- (i) A flameproof enclosure is one which will withstand without injury any explosion of the prescribed flammable gas that may occur within it under practical conditions of operation, and will prevent the transmission of flame such as will ignite the flammable gas in the surrounding atmosphere.



- (ii) Intrinsically safe apparatus is to be so constructed that when installed and operated under the conditions specified by the Certifying Authority, any electrical sparking that may occur in normal working, either in the apparatus or in its associated circuit, is incapable of causing an ignition of the prescribed flammable gas or vapour.

### Creepage and Clearance

110 The distances between live parts and between live parts and earthed metal whether across surfaces or in air shall be adequate for the working voltage having regard to the nature of the insulating material and the transient over-voltages developed by switch and fault conditions.

For bare busbars the following minimum clearance distances shall be observed:—

VOLTAGE BETWEEN PHASES OR POLES	MINIMUM CLEARANCE TO EARTH		MINIMUM CLEARANCE BETWEEN PHASES OR POLES	
	In air	In oil	In air	In oil
	mm	mm	mm	mm
660 or less	16	—	19	—
2200	38	—	38	—
3300	51	13	51	19
6600	63	19	89	25

Where necessary these figures are to be increased to allow for the electro-magnetic forces involved.

### Emergency Source of Power

111 An emergency source of power, capable of functioning when the ship is inclined 22.5 degrees and/or when the trim of the ship is 10 degrees, is to be installed in accordance with the following:—

Where emergency generating sets are fitted they are to be capable of being started readily when cold.

If hand starting is demonstrated to be practicable, alternative means of starting are not required. Where hand starting is not practicable other means are to be provided and, in general, should provide for not less than 12 starts in a period of 30 minutes without recourse to sources of power within the machinery space.

### PASSENGER SHIPS

1. A self-contained emergency source of electric power is to be installed above the bulkhead deck and outside the machinery casings. Its location in relation to the main source or sources of electric power is to be such as to ensure that a

fire or other casualty to the machinery spaces (i.e. spaces containing the main and auxiliary propelling machinery, boilers serving the needs of propulsion and all permanent coal bunkers) will not interfere with the supply or distribution of emergency power. It is not to be forward of the collision bulkhead.

2. The power available is to be sufficient to supply all services necessary for the safety of passengers and crew in an emergency, due regard being paid to such services as may have to be operated simultaneously. Special consideration is to be given to emergency lighting at every boat station on deck and oversides, in all alleyways, stairways and exits, in the machinery spaces and in the control stations (i.e. spaces in which radio, main navigating or central fire recording equipment or the emergency generator is located), to fire detection and alarm systems, to the sprinkler pumps, to navigation lights and to the daylight signalling lamp, if operated from the main source of power. The power is to be adequate for a period of 36 hours, except that in ships engaged regularly on voyages of short duration a lesser supply will be specially considered.

3. The emergency source of power is to be either:—

(a) A generator driven by a suitable prime mover with an independent fuel supply and with satisfactory starting arrangements; the fuel used is to have a flash point of not less than 43°C; or

(b) An accumulator (storage) battery capable of carrying the emergency load without recharging or excessive voltage drop.

4. (a) Where the emergency source of power is a generator a temporary source of emergency power is to be installed. This is to be an accumulator battery of sufficient capacity.

(i) To supply emergency lighting continuously for 30 minutes;

(ii) To close the watertight doors (if electrically operated) but not necessarily to close them simultaneously;

(iii) To operate the indicators (if electrically operated) which show whether power operated watertight doors are open or closed; and

(iv) To operate the sound signals (if electrically operated) which give warning that power operated watertight doors are about to close.

(v) To operate the fire detection and alarm systems.

Arrangements are to be such that the temporary source of emergency power will come into operation automatically in the event of failure of the main electrical supply.



(b) Where the emergency source of power is an accumulator battery arrangements are to be such that emergency lighting will automatically come into operation on failure of the main lighting supply.

5. An indicator is to be mounted in the machinery space, preferably on the main switchboard, to indicate when any accumulator battery fitted in accordance with this Rule is being discharged.

6. (a) The emergency switchboard is to be installed as near as is practicable to the emergency source of power.

(b) Where the emergency source of power is a generator, the emergency switchboard is to be located in the same space as the emergency source of power, unless the operation of the emergency switchboard would thereby be impaired.

(c) No accumulator battery fitted in accordance with this Rule is to be installed in the same space as the emergency switchboard.

(d) The emergency switchboard may be supplied from the main switchboard during normal operation.

### CARGO SHIPS

1. A self-contained emergency source of power is to be fitted. This may be either:—

(a) An accumulator (storage) battery capable of carrying the emergency load without recharging or excessive voltage drop; or

(b) A generator driven by a suitable prime mover with an independent fuel supply and with satisfactory starting arrangements; the fuel is to have a flash point not less than 43°C.

2. CARGO SHIPS OF 5000T GROSS TONNAGE AND ABOVE

(a) The emergency source of power is to be located above the uppermost continuous deck and outside the machinery casings.

(b) The power available is to be sufficient to supply all services necessary for the safety of all on board in an emergency.

Special consideration is to be given to:—

(i) Emergency lighting at every boat station on deck and oversides, in all alleyways, stairways and exits, in the main machinery space and the main generating set space, on the navigating bridge and in the chart room.

(ii) The general alarm.

(iii) Fire detection and alarm systems.

(iv) Navigation lights if solely electric and the daylight signalling lamp if operated by the main source of power.

(c) The power is to be adequate for at least 6 hours operation.

3. CARGO SHIPS OF LESS THAN 5000T GROSS TONNAGE

The emergency source of power is to be capable of supplying the illumination at launching stations and stowage positions of survival craft in addition to the emergency lighting, together with the fire detection and alarm systems.

The power available is to be adequate for at least 3 hours operation.

## Section 2

### SYSTEMS OF SUPPLY

201 The following systems of distribution may be used:—

(a) Parallel systems with constant pressure

#### DIRECT CURRENT

Two wire

Three wire with mid-wire earthed.

#### ALTERNATING CURRENT

Single-phase—two wire

Three-phase—

Three wire

Four wire with neutral earthed but without hull return.

Systems employing hull return may be submitted for special consideration.

(b) Series systems with constant current (direct current only).

202 For parallel systems with constant pressure, system voltages for both alternating current and direct current shall not exceed:—

500 V for generation, power, cooking and heating equipment permanently connected to fixed wiring.

250 V for lighting, heaters in cabins and public rooms, and other applications not mentioned above.



**203** In very large alternating current installations generation and limited distribution at higher voltages (e.g. 3,3 kV) may be submitted for special consideration. *See* M 18.

### Section 3

#### DIVERSITY FACTOR

**301** Circuits supplying two or more final sub-circuits are to be rated in accordance with the total connected load subject, where justified, to the application of a diversity factor. Where spare ways are provided on a section or distribution board an allowance for future increase of load is to be added to the total connected load before application of any diversity factor.

The diversity factor may be applied to the calculation for size of cable and rating of switchgear and fusegear.

#### Winch Circuits

**302** For winches the diversity factor is to be calculated and submitted.

### Section 4

#### ROTATING MACHINERY

##### Governors

**401** Where a turbine driven direct current generator is arranged to run in parallel with other generators, a switch is to be fitted to each turbine to open the generator circuit-breaker when the overspeed protective device functions. *See* H 828 and H 926.

**402** The facilities for adjusting the governor of an alternating current generating set, at normal frequency, are to be sufficiently fine to permit an adjustment of load on the engine within 5 per cent of full load.

##### Number of Generators

**403** The number and ratings of ships' service generating sets and converting sets are to be sufficient to ensure the operation of services essential for the propulsion and safety of the ship even when one generating set or converting set is out of service. *See* N 318 for ships with class notation RMC.

##### Rating

**404** Ships' service generators, including their exciters and continuously rated motors are to be suitable for continuous duty at their full rated output at maximum cooling

air or water temperature for an unlimited period, without the limits of temperature rise in 405 being exceeded. Other generators and motors are to be rated in accordance with the duty which they are to perform and when tested under rated load conditions the temperature rise is not to exceed the values in 405.

#### Temperature Rise

##### 405 SHIPS FOR UNRESTRICTED SERVICE

Table M 4.1 gives the limits of temperature rise above the cooling air temperature for machines not fitted with water coolers and above the cooling water temperature for machines fitted with coolers, for machines intended to operate in ships classed for unrestricted service.

##### SHIPS FOR RESTRICTED SERVICE (*See* M 106)

For machines intended to operate in ships classed for restricted service as defined in M 106 the temperature rises given may be increased by 5°C for all machines.

*If it is known that the temperature of the cooling medium exceeds the values given in M 106 the permissible temperature rise is to be reduced by an amount equal to the excess temperature of the cooling medium.*

**406** The limits of temperature rise of electric slip couplings are to be in accordance with Table M 4.1 except that when a squirrel cage element is used the temperature of this element is not to reach an injurious value. The temperature of the field windings is not to exceed these limits at all speeds of operation. Arrangements for reducing the excitation of self-ventilated couplings at low operational speeds are permissible.

**407** Alternating current machines of 5000 kVA output and above, and propulsion motors having a total axial core length of 1 m or more are to have at least three embedded temperature detectors. With multi-core machines the total length is to be taken as the sum of the individual core lengths.

#### Overloads

**408** Machines are to withstand, on test, without injury, the following momentary overloads:—

**GENERATORS:** An excess current of 50 per cent for 15 seconds after attaining the temperature rise corresponding to rated load, the terminal voltage being maintained as near the rated value as possible. The foregoing does not apply to the overload torque capacity of the prime mover.

TABLE M 4.1

## TEMPERATURE RISE IN DEGREES CENTIGRADE

ITEM	PART OF MACHINES	METHOD OF MEASUREMENT OF TEMPERATURE	TEMPERATURE-RISE °C					
			Air-cooled machines Class			Water-cooled machines Class		
			A	E	B	A	E	B
1. (a)	A.C. windings of turbine-type machines having output of 5000 kVA or more ...	ETD or R	50	60	70	70	80	90
(b)	A.C. windings of salient-pole and of induction machines having output of 5000 kVA or more, or having a core length of one metre or more ...							
2. (a)	A.C. windings of machines smaller than in Item 1 ...	R	50	65	70	70	85	90
(b)	Field windings of a.c. and d.c. machines having d.c. excitation other than those in Items 3 and 4 ...							
(c)	Windings of armatures having commutators ...	T	40	55	60	60	75	80
3.	Field windings of turbine-type machines having d.c. excitation ...	R	—	—	80	—	—	100
4. (a)	Low-resistance field windings of more than one layer, and compensating windings ...	T, R	50	65	70	70	85	90
(b)	Single-layer windings with exposed bare surfaces ...	T, R	55	70	80	75	90	100
5.	Permanently short-circuited insulated windings ...	T	50	65	70	70	85	90
6.	Permanently short-circuited windings, uninsulated ...	T	The temperature-rise of these parts shall in no case reach such a value that there is a risk of injury to any insulating or other material on adjacent parts					
7.	Iron core and other parts not in contact with windings ...							
8.	Iron core and other parts in contact with windings ...	T	50	65	70	70	85	90
9.	Commutators and slip-rings, open or enclosed ...	T	50	60	70	70	80	90

## NOTES

1. T = Thermometer method  
R = Resistance method  
E.T.D. = Embedded temperature detector
2. When the commutators, sliprings or bearings of machines provided with water coolers are not in the enclosed air circuit cooled by the water cooler, but are cooled by the ambient cooling air, the permissible temperature-rise above the ambient cooling air should be the same as for ventilated machines.
3. When Class F or Class H insulation is employed the permitted temperature rises are respectively 20degC and 40degC higher than the values given for Class B insulation.
4. Classes of insulation are to be in accordance with IEC Publication 85 (1957)—*Recommendations for the Classification of Material for the Insulation of Electrical Machinery and Apparatus* in relation to their thermal stability in service.



**MOTORS:** At rated speed or, in the case of a range of speeds, at the highest and lowest speeds, under gradual increase of torque the appropriate excess torque given below. Synchronous motors and synchronous induction motors are required to withstand the excess torque without falling out of synchronism and without adjustment of the excitation circuit preset at the value corresponding to rated load.

D.C. motors	... ..	50% for 15 seconds
Polyphase A.C. synchronous motors	... ..	50% for 15 seconds
Polyphase A.C. synchronous induction motors	... ..	35% for 15 seconds
Polyphase A.C. induction motors	... ..	60% for 15 seconds

The overload tests for propulsion machines will be specially considered for each installation.

#### Short-circuit

**409** The stator and rotor windings of alternating current propulsion generators are to be capable of withstanding a momentary short-circuit at the terminals of the machine applied when generating full rated voltage. Ships' service generators are to be capable of withstanding the mechanical and thermal effects of fault current for the duration of any time delay which may be fitted in a tripping device for discrimination purposes.

#### Shaft Currents

**410** Means are to be taken to prevent the ill effects of flow of currents circulating between the shaft and bearings.

#### Welding on Shafts

**411** Where welding is applied to shafts of machines for securing armature arms or spiders, stress relieving is to be carried out after welding.

#### Brushgear

**412** The final running position of brushgear is to be clearly and permanently marked.

Direct current motors and generators are to work with fixed brush setting from no load to the momentary overload specified without injurious sparking.

Alternating current commutator motors are to work over the specified range of load and speed without injurious sparking.

#### Direct Current Service Generators

**413** Automatic voltage regulators are to be provided for shunt wound direct current generators.

**414** Direct current generators used for charging batteries without series-regulating resistors are to be either

(i) shunt wound

or (ii) compound wound with switches arranged so that the series winding can be switched out of service.

**415** Means are to be provided at the switchboard to enable the voltage of each generator to be adjusted separately.

For each direct current generator, coupled to its prime mover, at any temperature within the working range the means provided is to be capable of adjusting the voltage at any load between no load and full load to within:—

0.5 per cent of rated voltage for generators of rating exceeding 100 kW.

1.0 per cent of rated voltage for generators of rating not exceeding 100 kW.

**416** The inherent regulation of ships' service generators is to be such that the following conditions are satisfied:—

For shunt or stabilized shunt wound generators when the voltage has been set at full load, the steady voltage at no load shall not exceed 115 per cent of the full load value, and the voltage obtained at any intermediate value of load shall not exceed the no load value.

For compound wound generators with the generator at full load operating temperature and starting at 20 per cent load with voltage within 1 per cent of rated voltage, then at full load the voltage is to be within 2.5 per cent of rated voltage. The average of the ascending and descending load/voltage curves between 20 per cent load and full load is not to vary more than 4 per cent from rated voltage.

**417** Generators are to be capable of delivering continuously the full load current and normal rated voltage at the terminals when running at full load engine speed at all ambient temperatures up to the specified maximum.

**418** Generators required to run in parallel are to be stable from no load up to the total combined load of the group and load sharing is to be satisfactory.

**419** The series winding of each two-wire generator is to be connected to the negative terminal.



420 Equalizer connections are to have a cross-sectional area appropriate to the system but in no case less than 50 per cent of that of the negative connection from the generator to the switchboard.

#### Alternating Current Service Generators

421 Each alternating current service generator, unless of the self-regulated type, is to be operated in conjunction with a separate automatic voltage regulator.

422 The voltage regulation of any alternating current generator with its AVR is to be such that at all loads from zero to full load the rated voltage at rated power factor is maintained under steady conditions within  $\pm 2.5$  per cent.

423 In alternating current systems with one generator set out of action, the remaining set(s) are to have sufficient reserve capacity to permit the starting of the largest motor in the ship without causing any motor to stall or any other device to fail due to excessive voltage drop on the system.

424 Alternating current generators required to run in parallel are to be stable from 20 per cent full load (kW) up to the total combined full load (kW) of the group and load sharing is to be satisfactory.

425 When generators are operated in parallel the kVA loads of the individual generating sets are not to differ from their proportionate share of the total kVA load by more than 5 per cent of the rated kVA output of the largest machine when operating at 0.8 power factor.

#### Inspection and Testing

426 On machines for essential services tests are to be carried out and a certificate furnished by the manufacturer. The tests are to include temperature rise, momentary overload, high voltage, and commutation. The insulation resistance and the temperature at which it was measured shall be recorded. Shaft materials are to comply with Chapter Q.

Generators and motors of 100 kW or over intended for essential services are to be inspected by the Surveyors during manufacture and testing. (A list of essential services is given in M 2102). Shaft materials are to be tested in accordance with Q 6.

427 In the case of duplicate machines, type tests of temperature rise, excess current and torque and commutation taken on a machine identical in rating and in all other essential details may be accepted in conjunction with

abbreviated tests on each machine. Acceptance of type tests is not to apply to propulsion machines. For the abbreviated tests, each machine is to be run and is to be found electrically and mechanically sound and is to have a high voltage test and insulation resistance recorded.

#### High Voltage Test

428 A high voltage test of 1000 V plus  $2 \times$  rated voltage with a minimum of 2000 V is to be applied to new machines preferably at the conclusion of the temperature rise test. The test is to be applied between the windings and the frame with the core connected to the frame and to any windings (or sections of windings) not under test. Where both ends of each phase are brought out to accessible separate terminals each phase is to be tested separately. The test is to be made with alternating voltage at any convenient frequency between 25 and 100 Hz of approximately sine wave form. The test is to be commenced at a voltage of about one-third the test voltage and is to be increased to full value as rapidly as is consistent with its value being indicated by the measuring instrument. The full test voltage is then to be maintained for one minute, and then reduced to one-third full value before switching off.

When it is desired to make additional high voltage tests on a machine which has already passed its tests the voltage of such additional tests is to be 75 per cent of the figure given above.

#### Motors for Refrigerated Cargo Services

429 Motors intended for coupling to fans for the circulation of air in refrigerated cargo spaces are to be inspected by the Surveyors during manufacture and testing.

Plans showing the construction of the motors are to be submitted for consideration.

Fan motors fitted in the air stream are to be totally enclosed or otherwise suitably enclosed to withstand the effects of excessive moisture where they are fitted between the two sections of a cooler or where the air from the cooler passes over the motor.

The Surveyors will witness a type test on the first motor of each size and type and works test certificates are to be supplied for the remainder. This type test may also be accepted for repeat orders of motors identical in all essential respects provided cross-references are given in the works test certificates. Type tests need not be carried out for motors of the same frame size as one previously tested for higher output.



Where motors are mounted in the air stream but are to be tested in still air conditions generally two conditions arise:—

- (a) The motor may be open at one end or both ends when tested but totally enclosed when mounted in the air stream. In such cases a type test should be carried out under working conditions, i.e. in the trunking with the fan and fairings in place, or alternatively, calculations furnished to show that the Rules for temperature rise are complied with.
- (b) The motor may be totally enclosed but with streamlined fairings. These may be accepted if, when tested in still air, the temperature rises are within the requirements of the Rules for totally enclosed motors. If they are outside these requirements the procedure in (i) is to be followed.

#### Electric Slip Couplings

430 Slip couplings are to be inspected by the Surveyors during manufacture and testing. Unless otherwise approved, every coupling is to be tested at the makers' works, the tests to include:—

Temperature rise test.

High voltage test.

Insulation resistance is to be recorded, together with the temperature at which it was measured.

### Section 5

#### DISTRIBUTION

##### Final Sub-circuits

501 A final sub-circuit of rating exceeding 15A is not to supply more than one point. The number of lighting points supplied by a final sub-circuit of rating 15A or less is not to exceed:—

for 24— 55 V circuits	10,
„ 110—127 V „	14,
„ 220—250 V „	18,

except that in final sub-circuits for cornice lighting, panel lighting and electric signs where lampholders are closely grouped the number of points supplied is unrestricted provided the maximum operating current in the sub-circuit does not exceed 10A.

502 A separate final sub-circuit is to be provided for every motor required for essential services.

503 Lighting circuits are to be supplied by final sub-circuits separate from those for heating and power. (This does not apply to cabin fans and wardrobe heaters.)

504 Lighting of cargo spaces and coal bunkers is to be controlled by multi-pole linked switches situated outside these spaces. Provision is to be made for the complete isolation of these circuits and locking in the off position of the means of control.

#### Navigation Lights

505 Navigation lights are to be connected separately to a distribution board reserved for this purpose only, and connected directly or through transformers to the main or emergency switchboard. The distribution board is to be accessible to the officer of the watch.

Each navigation light is to be controlled and protected in each insulated pole by a switch and fuse or circuit-breaker mounted on the distribution board.

Where the navigation panel is situated in the midships house, the midships sub-switchboard is regarded as an extension of the main switchboard providing it is supplied from the main switchboard by two cables each capable of carrying full load.

Each navigation light is to be provided with an automatic indicator giving aural and/or visual indication of failure of the light. If an aural device alone is fitted it is to be connected to a primary or secondary battery. If a visual signal is used connected in series with the navigation light means are to be provided to prevent extinction of the navigation light due to failure of the signal. The requirements of this paragraph do not apply to tugs, trawlers, fishing and similar small vessels.

Provision is to be made on the bridge for such navigation lights to be transferred to an alternative circuit.

Any statutory requirements of the country of registration are to be complied with and may be accepted as an alternative to the above.

#### Steering Gear

506 (a) Only short-circuit protection and overload alarm are to be provided in steering gear circuits.

(b) Indicators for running indication of steering gear motors are to be installed.

The exact position of the rudder, if power operated, is to be indicated at the principal steering station.



(c) In all passenger ships and in cargo ships of 5000T gross tonnage and upwards electric and electro-hydraulic steering gear is to be served by two circuits fed from the main switchboard. One of the circuits may pass through the emergency switchboard. Each circuit is to have adequate capacity for supplying all the motors which are normally connected to it and which operate simultaneously.

If transfer arrangements are fitted in the steering gear room to permit either circuit to supply any motor or combination of motors, the capacity of each circuit is to be adequate for the most severe load conditions.

The circuits are to be separated throughout their length as widely as is practicable.

(d) In cargo ships of less than 5000T gross tonnage where electric power is the sole source of power for both main and auxiliary steering gear the supply arrangements are to comply with (c) above.

If the auxiliary steering gear is powered by a motor primarily intended for other services alternative protective arrangements to that required by sub-para. (a) will be specially considered.

(e) Where electric control of the steering system is fitted an alternative control system is to be installed. This may be a duplicate electrical control system or control by other means.

#### Fire Detection, Alarm and Extinguishing Systems

507 (a) Where electrically driven emergency fire pumps are installed in accordance with F 403 and F 505, the supply to such pumps is not to pass through the main machinery spaces.

(b) Any fire alarm system is to operate both audible and visual signals at the fire detection control station(s). Detection systems for cargo spaces need not have audible alarms.

(c) Electrical equipment used in operating fire detecting equipment is to have two sources of electrical power, one of which is to be the emergency source. (See M 111 and F 105 with Footnote.)

In addition, the following apply to passenger ships:—

(d) Where automatic sprinkler systems are fitted and electrical power is used for the operation of sea water pumps, air compressors and alarms fitted in conjunction with such systems at least two sources of power are to be arranged. The sources of power are to be a main generator and the emergency source of power. (See M 111.) One supply is to be taken from the main switchboard by separate feeders reserved solely for this purpose. Such feeders are to be run

to a change-over switch situated near the sprinkler unit and the switch is to be normally closed to the feeder from the emergency switchboard. The change-over switch is to be clearly labelled and no other switch other than those at the switchboard(s) is permitted in these feeders.

In passenger ships with aluminium superstructures where feeders from the emergency generator to the sprinkler unit pass through any space constituting a fire risk the cables are to be of fireproof type.

#### Heating and Cooking

508 Each item of heating or cooking equipment is to be controlled as a complete unit by a multi-pole linked switch mounted in the vicinity of the equipment. In the case of cabin heaters a single pole switch will be acceptable.

#### Shore Supply

509 (a) Where arrangements are made for the supply of electricity from a source on shore or elsewhere a suitable connection box is to be installed in a position in the ship suitable for the convenient reception of flexible cables from the external source and containing a circuit-breaker or isolating switch and fuses and terminals of ample size and suitable shape to facilitate a satisfactory connection. Suitable cables, permanently fixed, are to be provided, connecting the terminals to a linked switch and/or a circuit-breaker at the main switchboard.

(b) For three-phase shore supplies with earthed neutral an earth terminal is to be provided for connecting the hull to the shore earth.

(c) The shore connection is to be provided with an indicator at the main switchboard in order to show when the cable is energized.

(d) Means are to be provided for checking the polarity (for direct current) or the phase sequence (for three-phase alternating current) of the incoming supply in relation to the ship's system.

(e) At the connection box a notice is to be provided giving full information on the system of supply and the normal voltage (and frequency if alternating current) of the ship's system and the procedure for carrying out the connection.

(f) Alternative arrangements may be submitted for consideration.

#### Submersible Bilge Pumps

510 Motors of permanently installed submersible bilge pumps are to be connected to the emergency switchboard (if fitted).



Cables and their connections to such pumps are to be capable of operating under a head of water equal to their distance below the bulkhead deck. The cables are to be suitable for operation in permanently wet situations, and installed in continuous lengths from above the bulkhead deck to the motor terminals.

Under all circumstances it is to be possible to start the motor of a permanently installed submersible bilge pump from a position above the bulkhead deck.

## Section 6

### SWITCHBOARDS, SWITCHGEAR AND PROTECTIVE EQUIPMENT

#### Switchboards

**601** (a) An unobstructed space is to be left in front of switchboards. Pipes should, so far as possible, not be installed directly above or in front of or behind switchboards. If such placing is unavoidable suitable protection is to be provided in these positions. See E 275.

(b) Where necessary the space at the rear of switchboards is to be ample to permit maintenance and in general not less than 0,6 m except that this may be reduced to 0,5 m in way of stiffeners or frames.

(c) For voltages between poles or to earth above 55 V a.c. or 250 V d.c. dead-front switchboards are to be used. Where live parts on a switchboard are adjacent to a gangway an insulated hand rail is to be provided and non-conducting mats or gratings are to be fitted at front and rear of the switchboard as necessary.

(d) Section and distribution boards are to be suitably enclosed unless they are installed in a cupboard or compartment to which only authorized persons have access, in which case the cupboard may serve as an enclosure.

All enclosures are to be constructed of, or lined with, non-flammable and non-hygroscopic material and are to be of robust construction.

(e) All measuring instruments and all apparatus controlling circuits are to be clearly and indelibly labelled for identification purposes. An indelible label is to be permanently secured to, or adjacent to, every fuse and every circuit-breaker and marked with particulars of the full load current of the generator or cable which the fuse or circuit-breaker protects. The labels for rewirable fuses are also to be marked with the appropriate size of fuse element. Where inverse time limit and/or reverse current devices are provided in connection with a circuit-breaker, the appropriate

settings of these devices are to be stated on the label. Nameplates are to be of flame-retardant material.

(f) In a passenger ship where there is only one main generating station the main switchboard is to be located in the same fire zone. Where there is more than one main generating station it is permissible to have only one main switchboard.

#### Busbars

**602** Busbars and their connections are to be of copper, all connections being made so as to inhibit corrosion. Busbars and their supports are to be so designed as to withstand the mechanical stresses which will arise during short-circuits. The maximum permissible temperature rise for bare conductors is 45°C.

#### Equalizer Connections

**603** The current rating of equalizer connections and equalizer switches is to be not less than half the rated full load current of the generator. The current rating of equalizer busbars is to be not less than half the rated full load current of the largest generator in the group.

#### Instruments for Direct Current Generators

**604** (a) For generators not operated in parallel at least one voltmeter and one ammeter are to be provided for each generator.

(b) For parallel operation one ammeter is to be provided for each generator, and two voltmeters. One voltmeter is to be connected to the busbars and the other is to be capable of measuring the voltage of any generator.

(c) For compound wound generators fitted with equalizer connections the ammeter is to be connected to the pole opposite to that connected to the series winding of the generator.

(d) For three-wire generators the ammeter is to be located between the equalizer connection and the generator.

(e) For three-wire systems supplied by a three-wire generator or by a balancing booster an ammeter is to be connected to each outer pole of each balancing generator and a voltmeter between each pole of the busbars and the middle wire.

#### Instruments for Alternating Current Generators

**605** (a) For alternating current generators not operated in parallel each generator is to be provided with at least one voltmeter, one frequency meter and one ammeter with an ammeter switch to enable the current in each phase to be read or an ammeter in each phase and for generators above 50 kVA a wattmeter.



(b) For alternating current generators operated in parallel each generator is to be provided with a wattmeter, and an ammeter in each phase conductor or an ammeter with a selector switch to permit the measuring of current in each phase.

For paralleling purposes two voltmeters, two frequency meters and a synchronizing device comprising either a synchroscope and lamps, or an equivalent arrangement, are to be provided. One voltmeter and one frequency meter are to be connected to the busbars, the other voltmeter and frequency meter are to be switched to enable the voltage and frequency of any generator to be measured.

#### Instrument Scales

**606** (a) The upper limit of the scale of every voltmeter is to be approximately 120 per cent of the normal voltage of the circuit and the normal voltage is to be clearly indicated.

(b) The upper limit of the scale of every ammeter is to be approximately 130 per cent of the normal rating of the circuit in which it is installed. Normal full load is to be clearly indicated.

(c) Ammeters for use with direct current generators and kW meters for use with alternating current generators which may be operated in parallel are to be capable of indicating 15 per cent reverse current or power respectively.

#### Instrument Transformers

**607** The secondary windings of instrument transformers are to be earthed.

#### Earth Indication

**608** Every insulated distribution system is to be provided with lamps or other means to indicate the state of insulation from earth.

#### Protection

**609** Installations are to be protected against accidental overcurrents including short-circuit. The protective devices are to provide complete and co-ordinated protection to ensure:—

- (a) Continuity of service under fault conditions through discriminative action of the protective devices.
- (b) Elimination of the fault so as to reduce damage to the system and hazard of fire.

#### Protection against Overload

**610** Circuit-breakers and automatic switches provided for overload protection are to have tripping characteristics

appropriate to the system. Fuses above 320A are not to be used for overload protection, but may be used for short-circuit protection.

Over-current releases of circuit-breakers for generators and for circuits with preference tripping are to be adjustable.

**NOTE.** Overload is considered to be an overcurrent in a circuit in which the insulation is still effective. Short-circuit is considered to be an over-current in a circuit in which the insulation is defective.

#### Protection against Short-circuit

**611** Protection against short-circuit currents is to be provided by circuit-breakers or fuses.

The breaking capacity of every protective device is to be not less than the maximum value of the short-circuit current which can flow at the point of installation at the instant of contact separation.

The making capacity of every circuit-breaker or switch intended to be capable of being closed, if necessary, on short-circuit, is to be not less than the maximum value of the short-circuit current at the point of installation. On alternating current this maximum value corresponds to the peak value allowing for maximum asymmetry.

Every protective device or contactor not intended for short-circuit interruption is to be adequate for the maximum short-circuit current which can occur at the point of installation having regard to the time required for the short-circuit to be removed.

In the absence of precise data the following short-circuit currents at the machine terminals are to be assumed:—

#### D.C. SYSTEMS

Ten times full load current for generators normally connected (including spare).

Six times full load current for motors simultaneously in service.

#### A.C. SYSTEMS

Ten times full load current for generators normally connected (including spare)—symmetrical RMS.

Three times full load current for motors simultaneously in service.

#### Combined Circuit-breakers and Fuses

**612** The use of a circuit-breaker of breaking capacity less than the prospective short-circuit current at the point of installation is permitted provided that it is preceded on the generator side by fuses, or by a circuit-breaker having at least the necessary breaking capacity. The generator breakers are not to be used for this purpose.



Fused circuit-breakers with fuses connected to the load side may be used where operation of the circuit-breaker and fuses is co-ordinated.

The characteristics of the arrangement shall be such that:—

- (a) When the short-circuit current is broken the circuit-breaker on the load side shall not be damaged and is to be capable of further service.
- (b) When the circuit-breaker is closed on the short-circuit current the remainder of the installation shall not be damaged. It is, however, admissible that the circuit-breaker on the load side may require servicing after the fault has been cleared.

#### Protection of Circuits

**613** Short-circuit protection is to be provided in each live pole of a direct current system and in each phase of an alternating current system.

Overload protection is to be provided in:—

Two-wire d.c. or single-phase a.c. system—at least one line or phase.

Three-wire d.c. system—both outer lines.

Insulated three-phase a.c. system—at least two phases.

Earthed three-phase a.c. system—all three phases.

No fuse, non-linked switch or non-linked circuit-breaker is to be inserted in an earthed conductor. Any switch or circuit-breaker fitted is to operate simultaneously in the earthed conductor and the insulated conductors.

These requirements do not preclude the provision (for test purposes) of an isolating link to be used only when the other conductors are isolated.

#### Protection of Generators

**614** In addition to over-current protection the following protective gear is to be provided as a minimum:—

(a) For generators not arranged to run in parallel: A circuit-breaker arranged to open simultaneously all insulated poles or in the case of generators rated at less than 50 kW a multi-pole-linked switch with a fuse in each insulated pole.

(b) For generators arranged to operate in parallel: A circuit-breaker arranged to open simultaneously all insulated poles. This circuit-breaker is to be provided with:—

- (i) For direct current generators, instantaneous reverse-current protection operating at not more than 15 per cent rated current.

- (ii) For alternating current generators a reverse-power protection, with time delay, selected and set within the limits of 2 per cent to 15 per cent of full load to a value fixed in accordance with the characteristics of the prime mover.

The reverse-current protection is to be adequate to deal with the reverse-current conditions emanating from the ship's network, e.g. cargo winches. The reverse-power protection specified for alternating current generators may be replaced by other devices ensuring adequate protection of the prime movers.

(c) In addition, the following is to be provided for direct current generators arranged to operate in parallel.

- (i) Where an equalizer connection is in use the reverse-current protection is to be provided in the pole opposite to that in which the series winding is connected.

- (ii) For compound generators an equalizer switch for each generator so interlocked that it closes before and opens after the main contacts of the circuit-breaker with which it is associated, or a three-pole circuit-breaker with all poles operating simultaneously.

- (iii) In three-wire systems a switch in the connection to the middle wire so interlocked with the generator switch or circuit-breaker connected to the outers as to operate simultaneously with them.

#### Essential Services

**615** Where generators are operated in parallel and essential machinery is electrically driven arrangements are to be made to disconnect automatically the excess non-essential load when the generators are overloaded.

If required this load shedding may be carried out in one or more stages.

Circuits for cargo refrigeration machinery are to be included in the last group to be disconnected.

#### Power Transformers

**616** The primary circuits of power transformers are to be protected against short-circuit by circuit-breakers or fuses.

When transformers are arranged to operate in parallel, means of isolation are to be provided on the secondary windings. Switches and circuit-breakers are to be capable of withstanding surge currents.



**Feeder Circuits**

**617** Isolation and protection of each main distribution circuit is to be ensured by a multi-pole circuit breaker or switch and fuses. Protection is to be in accordance with 610, 611 and 613 except that steering gear circuits are to have short-circuit protection only and overload alarm. The protective devices are to allow excess current to pass during the normal accelerating period of motors.

Circuits which supply motors fitted with overload protection may be provided with short-circuit protection only.

Motors of rating exceeding 0,5 kW and all motors for essential services are to be protected individually against overload and short-circuit. The short-circuit protection can be provided by the same protective device for the motor and its supply cable. For essential motors which are duplicated the overload protection may be replaced by an overload alarm if desired by the owner.

For motors intended to provide uninterrupted service the protective gear is to have a delay characteristic to enable the motor to start, yet which will operate on overload before the windings reach an unacceptably high temperature. The current which the protective device will allow to pass indefinitely is not to exceed 125 per cent of the rated current.

For motors for intermittent service the current setting and the delay are to be chosen in relation to the load factor of the motor.

Lighting circuits are to be provided with overload and short-circuit protection.

**Meters, Pilot Lamps, Capacitors**

**618** Protection is to be provided for voltmeters, voltage coils of measuring instruments, earth indicating devices and pilot lamps together with their connecting leads.

A pilot lamp installed as an integral part of another item of equipment need not be individually protected, provided it is fitted in the same enclosure. Where a fault in a pilot lamp would jeopardize the supply to essential equipment such lamps are to be individually protected.

Where capacitors for suppression of radio interference are fitted to busbars, generators, or steering gear, fuses of appropriate size are to be connected in the capacitor circuit.

**Switchgear**

**619** (a) Circuit-breakers and switches are to be of the air break type.

(b) The limits of temperature rise are to be based on the cooling air temperatures given in M 106 and are to comply with IEC Publication 157, *Low Voltage Distribution Switchgear*, or an equivalent National standard.

(c) Reports of tests, based on IEC Publication 157 or an equivalent National standard, are to be submitted for consideration when required.

(d) Each circuit opening device is to be so arranged that when placed in the OFF position it cannot accidentally move so as to close the circuit.

(e) Circuit-breakers are to be of the trip-free type.

(f) The overcurrent releases of circuit-breakers for generators and the setting of preference tripping relays are to be adjustable, or if of the non-adjustable type are to be readily replaceable by others of different values.

(g) Where reverse-power or reverse-current protection is provided it is to be appropriate to the circumstances of reverse-power between the limits of 2 per cent and 15 per cent of full load that may be expected. See 614(b).

(h) A fall of 50 per cent in the applied voltage shall not render the reverse-current mechanism inoperative although it may alter the amount of reverse-current required to open the breaker.

(i) Overcurrent releases are to be calibrated in amperes, and the settings marked on the circuit-breaker.

(j) Handles and operating mechanisms are to be so arranged that the hand of the operator cannot accidentally touch live metal or be injured through an arc arising from the switch or circuit-breaker, or the rupturing of a fuse. If switches are enclosed their handles are not to operate through unprotected slots.

**Testing**

**620** Before installation, switchboards complete or in sections with all components are to pass the following tests at the manufacturers' works and a certificate furnished. A high voltage test is to be carried out on all switching and control apparatus for systems greater than 60 V with a test voltage of 1000 V plus twice the rated voltage (minimum 2000 V) at any frequency between 25 and 100 Hz for one minute applied between (a) all current-carrying parts connected together and earth and (b) between current-carrying parts of opposite polarity or phase.

For systems of 60 V or less the test shall be at 500 V for one minute.

Immediately after the high voltage test the insulation resistance between (a) all current-carrying parts connected together and earth and (b) between current-carrying parts



of opposite polarity or phase, shall be not less than 1 megohm when tested with a d.c. voltage of at least 500 V.

Instruments and ancillary apparatus may be disconnected during the high voltage test.

#### Fuses

**621** Fuses are to comply with an approved National standard or with the recommendations of the International Electrotechnical Commission and with the following clauses.

The breaking capacity of the fuse is to be not less than the prospective short-circuit current at the point of installation.

Fuses are to be suitable for operating in the ambient temperatures given in M 106 and the temperature rise at the terminals is to be such that the maximum permissible temperature(s) of the connected cable(s) is not exceeded.

**622** Fuse-links and fuse-bases are to be marked with particulars of rated current and rated voltage. Each fuse position is to be permanently and indelibly labelled with the current-carrying capacity of the circuit protected by it and with the appropriate approved size of fuse or replaceable element.

**623** A list of approved fuses will be issued. To secure approval a report, preferably by an independent authority, is to be submitted giving details of test performance, fusing characteristics, temperature and insulation tests and details of the specification to which the fuse had been tested. Outline drawings are to be included but samples should not be submitted unless requested.

### Section 7

#### CONTROL GEAR

**701** Control gear is to comply with IEC Publication 158, *Low Voltage Control Gear*, or an equivalent National standard, and the remaining requirements of this Section.

The limits of temperature rise for control gear are to be based on the cooling air temperatures given in M 106.

**702** Control gear, including isolating and reversing switches is to be so arranged that shunt field circuits are not disconnected without an adequate discharge path being provided.

**703** Every electric motor is to be provided with efficient means of starting and stopping so placed as to be easily operated by the person controlling the motor. Every

motor above 0,5kW is to be provided with the following control apparatus:—

(a) Means to prevent undesired restarting after a stoppage due to low volts or complete loss of volts. This does not apply to motors, the continuous availability of which is essential to the safety of the ship.

(b) Efficient means of isolation are to be provided so that all voltage may be cut off from the motor and any associated apparatus including any automatic circuit-breaker.

Where the primary means of isolation (that provided at the switchboard, section board or distribution fuse board) is remote from a motor, one of the following is to be provided:—

(i) An additional means of isolation fitted adjacent to the motor.

or (ii) Provision made for locking the primary means of isolation in the OFF position.

or (iii) Provision made so that the fuses in each line can be readily removed and retained by authorized personnel.

(c) Means for automatic disconnection of the supply in the event of excess current due to mechanical overloading of the motor (this does not apply to steering motors). See also M 617.

(d) Where fuses are used to protect polyphase motor circuits, means are to be provided to protect the motor against unacceptable overload in the case of single phasing.

**704** When selecting motor control gear the maximum current of a motor is to be taken as the full load rated current of the motor.

**705** Where a single master-starter system (e.g. a starter used for controlling a number of motors successively) is used, the apparatus is to provide under-voltage and over-current protection and means of isolation for each motor not less effective than that required for systems using a separate starter for each motor. Where the starter is of the automatic type, suitable alternative means are to be provided for manual operation. Where the starter is used for motors for essential services the starting portion shall be duplicated and means are to be provided for the transfer of the starting duties in the event of failure of one of the starters.

**706** Means are to be provided for stopping ventilating fans serving machinery and cargo spaces. These means are to be capable of being operated from outside such spaces in case of fire.



Machinery driving forced and induced draught fans, independently driven pumps delivering oil to main propulsion machinery for bearing lubrication and piston cooling, oil fuel transfer pumps, oil fuel unit pumps and other similar fuel pumps are to be fitted with remote controls situated outside the space concerned so that they may be stopped in the event of fire arising in the space in which they are located.

In passenger ships carrying more than 36 passengers all power ventilation systems, except cargo and machinery space ventilation, which is to be in accordance with the first sub-paragraph, are to be fitted with master controls so that all fans may be stopped from either of two separate positions which are to be situated as far apart as practicable.

**707** Control gear and resistors are to be tested by the makers with a high voltage applied between the earthed frame and all live parts. The test voltage is to be 1000 V plus twice the rated voltage with a minimum of 2000 V. The voltage is to be alternating at any frequency between 25 and 100 Hz and is to be maintained for one minute without failure.

Immediately after the high voltage test the insulation resistance between (a) all current-carrying parts connected together and earth and (b) between current-carrying parts of opposite polarity or phase, shall be not less than 1 megohm when tested with a direct current voltage of at least 500 V. Instruments and auxiliary apparatus may be disconnected during the high voltage test.

## Section 8

### CABLES

#### Conductors

**801** High conductivity annealed copper only is to be used. For rubber-insulated cables the copper wire is to be tinned or alloy coated and the surface is to be bright.

Conductor composition and stranding is to be selected so that adequate flexibility of the finished cable is assured. Conductors of nominal cross-section 2,5 mm<sup>2</sup> and less need not be stranded. This requirement does not apply to mineral-insulated cables which have solid conductors. Cores of multi-core cables are to be readily identifiable.

#### Insulating Materials

**802** Permitted insulating materials with maximum rated conductor temperatures are given in Table M 8.1.

TABLE M 8.1

INSULATING MATERIAL	MAXIMUM RATED CONDUCTOR TEMP. °C
<i>Elastomeric Compounds</i>	
Natural or synthetic rubber (general purpose) ... ..	60
Butyl rubber ... ..	80
Ethylene propylene rubber ... ..	85
Cross-linked polyethylene ... ..	85
Silicone rubber ... ..	95
<i>Thermoplastic Compounds</i>	
Polyvinyl chloride (general purpose)	60
Polyvinyl chloride (heat resisting quality) ... ..	75
<i>Other Materials</i>	
Mineral ... ..	95

#### NOTES

1. Silicone rubber and mineral insulation may be used for higher temperatures (to 150°C for silicone rubber, unlimited for mineral insulation) when installed where they are not liable to be touched by ship's personnel. Proposals to employ these higher temperatures will be specially considered.

2. The temperature of the conductor is the combination of ambient temperature and temperature rise due to load.

Where a rubber or rubber-like material with maximum conductor temperature greater than 60°C is used it is to be readily identifiable.

Other insulating materials will be considered.

#### Insulation

**803** (a) ELASTOMERIC OR THERMOPLASTIC—The use of a single layer is permitted only when applied by the extrusion process. With other processes the insulation is to consist of at least two layers of compounds equal in quality, and the layers should be bonded together.

The insulating wall is to be close fitting but not adherent to the conductor.

(b) MINERAL INSULATION—Mineral insulation is to consist of a powdered mineral material, e.g. magnesium oxide, highly compressed between conductors and copper sheath. It is to be temperature-stable and non-corrosive to copper.

#### Construction

**804** Whatever the insulating material used both the belted and non-belted construction may be used for two, three and more conductor cables.



**Non-belted Cables**

805 For non-belted cables the spaces among the cores are to be filled with fibrous or rubber-like fillers and the cylindrical assembly is to be sheathed with the appropriate protective covering. Fillers may be omitted in multi-core cables having conductor sections 4.5 mm<sup>2</sup> or less.

Alternatively, elastomeric or thermoplastic insulated cables may have a compatible compound extruded over the cabled cores so as to form, in one body, the fillers and a continuous covering similar to a sheath.

**Belted Cables**

806 Belted cables are to be constructed as non-belted cables except that an insulating wall is to be applied to the cabled cores before applying the protective covering. For elastomeric or thermoplastic insulated cables the common belt is to be elastomeric or thermoplastic respectively, which may or may not form one body with the fillers.

**Fillers**

807 When fibrous fillers are used they are to consist of jute or similar rovings (including asbestos, glass, etc.), and are to be resistant to moisture.

When rubber-like fillers are used they are to consist of rubber (including regenerated and/or unvulcanized rubber) compounds or plastic compounds.

**Sheaths and Protective Coverings**

808 Cables are to be protected by one or more of the following and the sheath or protective covering is to be compatible with the insulation:—

SHEATH	Lead-alloy sheath
	Copper sheath
	Non-metallic sheath
PROTECTIVE COVERING	Steel-wire armour
	Steel-tape armour
	Metal-braid armour (basket weave)
	Fibrous braid.

Unsheathed cables, e.g. rubber-insulated taped and braided or equivalent may be used only if installed in conduit.

(a) LEAD-ALLOY SHEATH—This is to be one of the recommended lead alloys given in IEC Publication 92.

(b) COPPER—Copper sheath is permitted only for mineral-insulated cables.

(c) METAL-BRAID ARMOUR (Basket weave)—This is to be formed of galvanized steel, copper or copper alloy or aluminium alloy wires. Aluminium alloy is to be corrosion-

resistant. The coverage density of the braid is to be such that the weight of the braid is at least 90 per cent of the weight of a tube of the same metal having an internal diameter equal to the internal diameter of the braid and a thickness equal to the diameter of one of the wires forming the braid.

(d) STEEL-WIRE ARMOUR—This is to consist of galvanized-annealed-steel wires having an elongation at break of at least 12 per cent. The wires are to be applied over the bedding so as to form a uniformly cylindrical layer and so as to ensure adequate flexibility of the cable.

(e) STEEL-TAPE ARMOUR—This is to consist of annealed-steel tape. In general, the armour is to be formed of two tapes wound over the bedding in the same direction so that the gap in the first layer is not more than half the tape width and the second layer covers this gap with an overlap.

NOTE. Armour is to be protected against corrosion where necessary. A protective bedding is to be inserted beneath armour (of any type). This may be textile tape or braid, PCP tape or other suitable material. Textile materials are to be treated against moisture.

(f) NON-METALLIC SHEATH—Polychloroprene compound, polyvinyl chloride compound and chlorosulphonated polyethylene may be used for impervious sheaths. Other compounds will be considered.

(g) FIBROUS BRAID—Textile braid is to be of cotton, hemp, asbestos, glass, or other equivalent fibre and is to be of strength suitable for the size of the cable. It is to be effectively impregnated with a compound which is resistant to moisture, and flame retarding except where flame-extending cables are permitted by 813.

**Dimensions**

809 The thickness of insulation and sheath is to be generally in accordance with IEC Publication 92.

Cables with other dimensions but which comply with a National specification for marine cables may be submitted for consideration.

**Quality of Materials**

810 The quality of materials is to be in accordance with the recommendations of IEC Publication 92.

Alternative requirements of National Standards will be considered.

**Choice of Cables**

811 The rated voltage of any cable is to be not lower than the nominal voltage of the circuit for which it is used.

Cables exposed to voltage surges associated with highly inductive circuits, e.g. contactor operating circuits for winches, etc., require special consideration.



The rated operating temperature of the insulating material is to be at least 10degC higher than the maximum ambient temperature liable to be produced in the space where the cable is installed.

Where polyvinyl chloride insulation is employed, particular care should be taken to avoid damage to the sheathing during the fitting of watertight bulkhead glands.

#### Choice of Protective Covering

812 Cables fitted in the following locations:—

- Decks exposed to the weather
- Bathrooms
- Cargo holds
- Refrigerated spaces
- Machinery spaces

or in any other location where water condensation or harmful vapour (e.g. oil vapour) may be present are to have an impervious sheath. In permanently wet situations metallic sheaths are to be used for cables with hygroscopic insulation.

813 All cables are to be of flame-retardant or fire-resisting types except that flame-extending cables may be used for final circuits only in the following cases:—

(a) Where cables are installed in metallic conduits having an internal diameter not exceeding 25 mm and provided the conduits are mechanically and electrically continuous.

(b) Bare lead sheathed cable having conductor sections not exceeding 4,5 mm<sup>2</sup>.

#### Current Rating

814 The highest continuous load carried by a cable is not to exceed its current rating. The diversity factor of the individual loads and the duration of the maximum demand may be allowed for in estimating the maximum continuous load and is to be shown on plans submitted for approval.

The voltage drop from the main switchboard busbars to any point in the installation when the cables are carrying maximum current under normal conditions of service, is not to exceed 6 per cent of the nominal voltage.

In assessing the current rating of lighting circuits every lampholder is to be assessed at the maximum load likely to be connected to it, with a minimum of 60 watts, unless the fitting is so constructed as to take only a lamp rated at less than 60 watts.

Cables supplying cargo winches, cranes, windlasses and capstans are to be suitably rated for their duty. Unless the duty is such as to require a longer time rating, cables for winch or crane motors may be half hour rated on the basis

of the half hour kW rating of the motors. Cables for windlass and capstan motors are to be not less than one hour rated on the basis of the one hour kW rating of the motor. In all cases the rating is to be subject to the voltage drop being within the specified limits.

The current ratings given in Tables M 8.2 are based on maximum operating conductor temperatures given in Table M 8.1. Where a more precise evaluation of current rating has been carried out based on experimental or calculated data, details may be submitted for approval.

#### Correction Factors for Current Rating

815 (a) BUNCHING OF CABLES—Where more than six cables belonging to the same circuit are bunched together a correction factor of 0,85 is to be applied.

### CURRENT RATING IN AMPERES

(Based on ambient temperature 45°C)

TABLE M 8.2(a) GENERAL PURPOSE RUBBER AND PVC

NOMINAL CROSS-SECTION mm <sup>2</sup>	SINGLE CORE	2 CORE	3 OR 4 CORE
1	10	8	7
1,5	13	11	9
2,5	17	14	12
4	23	19	16
6	30	25	21
10	41	35	28
16	54	46	37
25	71	60	49
35	86	73	60
50	100	85	76
60	120	100	84
70	130	110	91
95	160	135	110
120	185	155	130
150	210	180	145
185	240	205	170
240	285	240	200
300	330	280	225
400	DC 390 AC 380	DC 330 AC 325	DC 275 AC 270
500	450 430	380 365	315 300
625	520 470	440 375	360 330



TABLE M 8.2(b) HEAT RESISTING PVC

NOMINAL CROSS-SECTION mm <sup>2</sup>	SINGLE CORE	2 CORE	3 OR 4 CORE
1	14	11	9
1,5	19	16	13
2,5	25	21	17
4	32	27	22
6	42	35	29
10	58	49	40
16	78	66	54
25	100	86	71
35	125	105	88
50	155	135	110
60	175	150	125
70	195	165	135
95	235	200	160
120	270	230	190
150	310	265	215
185	355	300	250
240	415	355	290
300	480	410	335
400	DC 570 AC 560	DC 485 AC 475	DC 400 AC 390
500	650 620	550 530	455 435
625	740 670	630 570	520 470

TABLE M 8.2(c) BUTYL

NOMINAL CROSS-SECTION mm <sup>2</sup>	SINGLE CORE	2 CORE	3 OR 4 CORE
1	15	12	10
1,5	21	18	15
2,5	27	23	19
4	36	31	25
6	46	39	32
10	62	53	43
16	83	70	58
25	110	93	77
35	135	115	94
50	160	135	115
60	185	160	130
70	205	175	145
95	250	210	175
120	290	245	205
150	330	280	230
185	375	320	260
240	445	380	310
300	510	435	355
400	DC 610 AC 590	DC 520 AC 500	DC 425 AC 415
500	690 640	590 550	485 450
625	790 690	680 580	550 480

(b) AMBIENT TEMPERATURE—When it is known that the ambient temperature is different from that given in M 106 the correction factors, as shown in Table M 8.3, are to be applied.

(c) INTERMITTENT SERVICE—Where the load is intermittent, the correction factors in Table M 8.4 may be applied for half hour and one hour ratings. In no case is a shorter rating than one half hour rating to be used, whatever the degree of intermittency.

#### Installation of Cables

816 Cable runs are to be, as far as possible, straight and accessible.

817 The installation of cables across expansion joints in the ship's structure is to be avoided. Where this is not practicable a loop of cable of length proportional to the expansion of the joint is to be provided. The internal radius of the loop is to be at least 12 times the external diameter of the cable.

818 Where a duplicate supply is required the two cables are to follow different routes which are to be as far apart as practicable.

819 Cables having insulating materials with different maximum-rated conductor temperatures are not to be bunched together, or, where this is not practicable, the cables are to be operated so that no cable reaches a temperature higher than that permitted for the lowest temperature-rated cable in the group.

820 Cables having a protective covering which may damage the covering of other cables are not to be bunched with those other cables.

821 When installing cables the minimum internal radius of bend is to be generally in accordance with Table M 8.6.

#### Mechanical Protection

822 Cables exposed to risk of mechanical damage are to be protected by metal channels or casing or enclosed

TABLE M 8.2(d) ETHYLENE PROPYLENE RUBBER,  
CROSS-LINKED POLYETHYLENE

NOMINAL CROSS-SECTION mm <sup>2</sup>	SINGLE CORE	2 CORE	3 OR 4 CORE
1	16	13	11
1,5	22	18	15
2,5	28	23	19
4	37	31	25
6	48	40	33
10	67	57	47
16	89	75	62
25	115	99	82
35	145	120	100
50	180	155	125
60	200	170	140
70	220	185	155
95	270	220	190
120	310	265	215
150	355	305	250
185	405	345	285
240	475	405	330
300	540	465	380
400	DC 650 AC 630	DC 550 AC 540	DC 455 AC 440
500	740 690	630 590	520 480
625	850 730	720 620	590 510

in steel conduit unless the protective covering (e.g. armour or sheath) is sufficient to withstand the possible damage.

**823** Cables in cargo holds and other spaces where there is exceptional risk of mechanical damage are to be suitably protected, even if armoured, unless the steel structure affords adequate protection. *See also* M 1607 and M 1608.

**824** Metal casings for mechanical protection of cables are to be efficiently protected against corrosion.

#### Earthing

**825** Metal coverings of cables are to be effectively earthed at both ends of the cable, except in final sub-circuits where earthing at the supply end only will be considered adequate. This does not necessarily apply to instrumentation cables where single point earthing may be desirable for technical reasons.

M 823 - M 827

TABLE M 8.2(e) SILICONE RUBBER, MINERAL

NOMINAL CROSS-SECTION mm <sup>2</sup>	SINGLE CORE	2 CORE	3 OR 4 CORE
1	20	17	14
1,5	24	20	17
2,5	32	27	22
4	42	36	29
6	53	45	37
10	73	62	51
16	98	83	69
25	130	110	91
35	165	140	115
50	200	175	145
60	230	195	160
70	250	215	175
95	310	265	215
120	360	305	250
150	420	355	290
185	485	410	340
240	570	485	400
300	660	560	460

**826** The electrical continuity of all metal coverings of cables throughout the length of the cable, particularly at joints and tapings is to be ensured.

**827** The lead sheath of lead-sheathed cables is not to be used as the sole means of earthing the non-current carrying parts of items of equipment.

TABLE M 8.3

INSULATION	CORRECTION FACTOR FOR AMBIENT TEMPERATURE			
	40°C	45°C	50°C	55°C
Rubber or PVC (general purpose) ... ..	1,15	1,00	0,82	—
PVC (heat-resisting quality)	1,08	1,00	0,91	0,82
Butyl rubber ... ..	1,07	1,00	0,93	0,85
Ethylene Propylene Rubber, Cross-linked Polyethylene	1,06	1,00	0,94	0,87
Mineral, Silicone Rubber ...	1,05	1,00	0,95	0,89



TABLE M 8.4

CORREC- TION FACTOR	HALF HOUR RATING		ONE HOUR RATING	
	With Metallic Sheath	Without Metallic Sheath	With Metallic Sheath	Without Metallic Sheath
1,0	mm <sup>2</sup> Up to 20	mm <sup>2</sup> Up to 75	mm <sup>2</sup> Up to 67	mm <sup>2</sup> Up to 230
1,1	21-40	76-125	68-170	231-400
1,15	41-65	126-180	171-290	401-600
1,2	66-95	181-250	291-430	
1,25	96-130	251-320	431-600	
1,3	131-170	321-400		
1,35	171-220	401-500		
1,4	221-270			

**Securing of Cables**

**828** Cables are to be effectively supported and secured without their coverings being damaged.

**829** The distances between supports is to be chosen according to the type of cable, the distances being generally in accordance with Table M 8.5.

**830** Supports and accessories are to be robust and are to be of corrosion-resistant material or suitably corrosion inhibited before erection.

**Penetration of Bulkheads and Decks**

**831** Penetration of watertight bulkheads or decks is to be carried out with either individual watertight glands or

with packed watertight boxes carrying several cables. However carried out the watertight integrity of the bulkheads or deck is to be maintained. *See also 811.*

**832** Cables passing through decks are to be protected by deck tubes or ducts.

**833** Where cables pass through non-watertight bulkheads or structural steel the holes are to be bushed with lead or other approved material. If the steel is 6 mm thick, adequately rounded edges may be accepted as the equivalent of bushing.

**834** Materials used for glands and bushings are to be such that there is no risk of corrosion.

**835** Where rectangular holes are cut in bulkheads or structural steel the corners are to be radiused.

**Installation in Pipes and Conduits**

If installed in pipe or conduit the following rules are to be complied with.

**836** Metal conduit systems are to be earthed and are to be mechanically and electrically continuous across joints. Individual short lengths of conduit need not be earthed.

**837** The internal radius of bend of pipes and conduit is to be not less than that laid down for cables provided that for pipes exceeding 64 mm diameter the internal radius of bend is not less than twice the diameter of the pipe.

**838** The drawing-in factor (ratio of the sum of the cross-sectional areas of the cables to the internal cross-section area of the pipe) is not to exceed 0,4.

**839** Expansion joints are to be provided where necessary.

**840** Where necessary, ventilation openings are to be provided at the highest and lowest points so as to permit air circulation and to prevent accumulation of water.

Where cables are laid in trunks the trunks are to be so constructed as not to afford passage for fire from one between deck or compartment to another.

**841** High voltage cables e.g. those used for cold cathode luminous discharge lamps, are not to be installed in metal conduit unless protected by metal sheath or screen.

**842** Non-metallic ducting or conduit is to be of flame-retardant material. PVC conduit is not to be used in refrigerated spaces or on open decks, unless specially approved.

TABLE M 8.5

EXTERNAL DIAMETER OF CABLE		NON- ARMoured CABLES	ARMoured CABLES
Exceeding	Not Exceeding		
mm	mm	mm	mm
—	8	200	250
8	13	250	300
13	20	300	350
20	30	350	400
30	—	400	450

**Installation in Refrigerated Spaces**

843 Cables installed in refrigerated spaces are to have a watertight or impervious sheath and are to be protected against mechanical damage. If an armoured cable is used the armour, unless galvanized, is to be protected against corrosion by a further moisture-resisting covering.

Cables entering a refrigerated space are to pass directly through the walls or lagging and are to be protected by a tube sealed at each end. Alternatively, the cables may be passed through solid door frames the necessary holes being sealed at each end.

Precautions are to be taken to prevent the placing of hooks round the cable as a casual means of suspension.

Where PVC insulated cables are used in refrigerated spaces a low temperature grade is to be used.

**Cables for Alternating Current**

844 Where it is necessary to use single-core cables for alternating current circuits rated in excess of 20 A the following rules are to be complied with:—

(a) Cables are to be either non-armoured or armoured with non-magnetic material.

(b) If installed in pipe or conduit, cables belonging to the same circuit are to be installed in the same conduit, unless the conduit or pipe is of non-magnetic material.

(c) Cable clips are to include cables of all phases of a circuit unless the clips are of non-magnetic material.

(d) When installing two, three or four single-core cables forming respectively single-phase circuits, three-phase circuits or three-phase and neutral circuits the cables are to be in contact with one another, as far as possible. In any event the distance between adjacent cables is not to be greater than one diameter.

(e) If single-core cables of current rating greater than 250 A are run along a steel bulkhead, wherever practicable the cables should be spaced away from the steel.

(f) Where single core cables of rating exceeding 50 A are used, magnetic material is not to be placed between single-core cables of a group. If these cables pass through steel plates, all cables of the same circuit are to pass through a plate or gland so constructed that there is no magnetic material between the cables and suitable clearance is provided between the cable core and magnetic material.

**TABLE M 8.6****MINIMUM INTERNAL RADII OF BENDS IN CABLES FOR FIXED WIRING**

INSULATION	FINISH	OVERALL DIAMETER	MINIMUM INTERNAL RADIUS OF BEND (TIMES OVERALL DIAMETER OF CABLE)
Elastomer or PVC (circular copper conductors)	Wire braid armoured and unarmoured	Not exceeding 10 mm	3
		Exceeding 10 mm but not exceeding 25 mm	4
		Exceeding 25 mm	6
	Spiral steel wire armoured	Any	6
Elastomer or PVC (shaped copper conductors)	Wire braid armoured, spiral steel wire armoured or unarmoured	Any	8
Mineral	Copper sheathed with or without PVC covering	Any	4



This clearance, wherever practicable, is to be not less than 75 mm when the current exceeds 300 A. For currents between 50 A and 300 A the clearance is to be obtained by interpolation.

#### Cable Ends

845 The ends of all conductors of cross-sectional area greater than 4 mm<sup>2</sup> are to be fitted with soldering sockets, compression type sockets or mechanical clamps. Corrosive fluxes are not to be used.

Cables having a hygroscopic insulation (e.g. mineral insulated) are to have their ends sealed against ingress of moisture.

Cables with a supplementary insulating belt beneath the protective sheath are to have additional insulation at those points where the insulation of each core makes or may make contact with earthed metal.

#### Joints and Branch Circuits

846 If a joint is necessary it is to be carried out so that all conductors are adequately secured, insulated and protected from atmospheric action. Terminals or busbars are to be of dimensions adequate for the cable rating.

#### Testing

847 Tests in accordance with the recommendations of IEC Publication 92 or the equivalent National Standard are to be made at the manufacturer's works prior to dispatch, and may be required to be carried out under the supervision of the Surveyors.

All main cables for electric propelling machinery are to be tested in the presence of the Surveyors.

### Section 9

#### TRANSFORMERS

901 The following Rules apply to all transformers for general use rated from 1 kVA to 1000 kVA inclusive and suitable for operating over an input voltage range up to 3300 volts line to line.

Transformers outside these limits will be specially considered.

#### Construction

902 Transformers except those for motor starting are to be double wound.

#### Liquid Cooled Transformers

903 Proposals for the use of liquid cooled transformers will be specially considered.

#### Number and Rating of Transformers

904 Where essential services are supplied the number and ratings of transformers are to be sufficient to ensure the operation of essential services even when one transformer is out of service.

#### Regulation

905 The inherent regulation at 0.8 power factor is not to exceed 5 per cent.

Regulation of the complete system is to comply with M 814.

#### Temperature Rise

906 The temperature rise of windings of dry type transformers above the ambient temperatures given in M 106, when measured by resistance, during continuous operation at the maximum rating is not to exceed:—

Class A 50°C

Class E 60°C

Class B 70°C

Proposals to use Class H or Class C insulation will be specially considered.

#### Short-circuit

907 All transformers are to be capable of withstanding, without damage, the thermal and mechanical effects of a short-circuit at the terminals of any winding for 2 seconds.

#### Tests

908 The following tests are to be carried out on all transformers at the manufacturers' works, and a certificate of tests issued by the manufacturer.

#### HIGH VOLTAGE TEST

(a) The voltage is to be applied to each winding in turn, between the winding under test and the remaining windings, core, frame and tank or casing connected together and to earth.

The test is to be made with 1 kV a.c. plus twice the highest voltage between lines with a minimum of 2.5 kV at any frequency between 25 and 100 Hz and maintained for 1 minute without failure.



**INDUCED HIGH VOLTAGE TEST**

(b) To test between turns, coils and terminals an a.c. voltage is to be applied between the above parts corresponding to twice the voltage appearing between these parts when rated voltage is applied to the terminals. The duration of the test is to be 1 minute for any test frequency up to and including twice the rated frequency.

**INSULATION RESISTANCE**

(c) The insulation resistance of each winding in turn to all the other windings, core, frame and tank or casing connected together and to earth is to be measured and recorded together with the temperature of the transformer at the time of the test.

**TEMPERATURE RISE**

(d) One transformer of each size and type is to be given a temperature rise test.

**Section 10****LIGHTING**

**1001** Lighting which is essential for the safety and the working of the ship is to comply with the following Rules:—

The voltage of tungsten filament lampholders is not to exceed:—

**BAYONET FITTING**

Normal	B 22	250 V
Small (single contact)	B 15s	130 V
Small (double contact)	B 15d	130 V

**SCREW FITTING**

Goliath	E 40	250 V
Medium	E 27	250 V
Small	E 14	250 V
Miniature	E 10	24 V

Lamps are to be in accordance with the following:—

- B 22 up to 200 W
- E 27 up to 200 W
- E 40 no limit

Lampholders are to be constructed of flame-retarding and non-hygroscopic material. All metal parts are to be of robust construction. Goliath lampholders are to be provided with means for locking the lamp in the holder. The temperature of cable connections is not to exceed the maximum conductor temperature permitted for the cable given in M 802.

**Fluorescent Lighting**

**1002** Fittings, reactors, capacitors and other auxiliaries are not to be mounted on surfaces which are subject to high temperatures. In ships for unrestricted service they are to be capable of operating at the ambient temperatures given in M 106.

Capacitors of 0.5 microfarads and above are to be provided with a means of prompt discharge on disconnection of the supply.

Inductors and high reactance transformers are to be installed as close as practicable to the associated discharge lamp.

**1003** Where cold cathode luminous discharge lamps of normal operating voltage above 250 V are used a warning notice calling attention to the voltage is to be displayed at points of access to the lamps and where otherwise necessary.

**1004** Emergency lighting is to be fitted in accordance with M 111.

**Section 11****ACCESSORIES****Enclosures**

**1101** Enclosures are to be of metal or of flame-retardant insulating materials.

**Inspection and Draw Boxes**

**1102** If metal conduit systems are used inspection and draw boxes are to be of metal and are to be in rigid electrical and mechanical connection with the conduits.

**Socket Outlets and Plugs**

**1103** Where it is necessary to earth the non-current-carrying parts of portable or transportable equipment an effective means of earthing is to be provided at the socket outlet.

On weather decks, galleys, laundries, machinery spaces and all wet situations, socket outlets and plugs are to be effectively shielded against rain or spray and are to be provided with means of maintaining this quality after removal of the plug.

The temperature rise on the live parts of socket outlets and plugs is not to exceed 30°C. Socket outlets and plugs are to be so constructed that they cannot be readily short-circuited whether the plug is in or out, and so that a pin of the plug cannot be made to earth either pole of the socket outlet.

All socket outlets of current rating 15 A or more are to be provided with a switch.



**Section 12****HEATING AND COOKING EQUIPMENT**

1201 Heaters are to be so constructed, installed and protected that clothing, bedding and other flammable material cannot come in contact with them in such a manner as to cause risk of fire. There is to be no excessive heating of adjacent bulkheads or decks.

**Section 13****BATTERIES**

The following Rules apply to permanently installed secondary batteries.

**Construction**

1301 The cells of all batteries are to be so constructed and secured as to prevent spilling of the electrolyte due to the motion of the ship, and to prevent emission of acid or alkaline spray.

**Location**

1302 Alkaline batteries and lead acid batteries are not to be installed in the same compartment.

Large batteries are to be installed in a space assigned to the batteries only or alternatively in a deck box if such a space is not available.

Engine starter batteries are to be located as close as practicable to the engine(s) served. If such batteries cannot be accommodated in the battery room they are to be installed so that adequate ventilation is ensured.

**Lining of Compartments**

1303 Where acid is used as the electrolyte a tray of lead, or wood lined with lead, is to be provided below the cells. Alternatively, the deck below the cells is to be protected with lead or other acid-resisting material so as effectually to prevent any acid from lodging in contact with the ship's structure.

The interiors of all battery compartments including shelves are to be painted with corrosion-resistant paint.

**Equipment**

1304 Switches, fuses and other electrical equipment liable to cause an arc are not to be fitted in battery compartments.

**Supports**

1305 Batteries are to be so arranged that each cell or crate of cells is accessible from the top and at least one side.

Cells or crates are to be carried on non-absorbent insulating supports. Similar insulators are to be fitted to prevent any movement of cells arising from the motion of the ship.

**Ventilation**

1306 Battery compartments are to be ventilated by an independent ventilating system.

Natural ventilation may be employed if ducts can be run directly from the top of the compartment to the open air with no part of the duct more than 45° from the vertical. If natural ventilation is impracticable mechanical ventilation is to be provided. Interior surfaces of ducts and fans are to be painted with corrosion-resistant paint. Fan motors are not to be located in the air stream.

All openings through the battery compartment bulkheads or decks, other than ventilation openings are to be effectively sealed to reduce the possibility of escape of gas from the battery compartment, into the ship.

Where practicable, battery lockers are to be ventilated similarly to battery compartments.

Deck boxes are to be adequately ventilated and means provided to prevent ingress of water.

**Size of Batteries and Charging Facilities**

1307 Where batteries are used for starting main engines at least two batteries are to be fitted of such combined size that H 614 is complied with.

Adequate charging facilities are to be provided and where batteries are charged from line voltage, by means of a series resistor, protection against reversal of current is to be provided when the charging voltage is 20 per cent of line voltage or higher.

In d.c. systems means are to be provided to isolate the batteries from the low voltage system when being charged from a higher voltage system.

**Protection**

1308 Batteries, except starter batteries, are to be protected against short-circuit by a fuse in each insulated conductor or a multi-pole circuit-breaker at a position adjacent to the battery compartment.

1309 A permanent notice is to be fitted to all battery compartments prohibiting naked lights and smoking.

**Section 14****INTERNAL COMMUNICATIONS**

1401 Where a communication circuit takes its supply direct from power or lighting circuits and in other cases where the voltage of supply exceeds 50 V a.c. or 60 V d.c.



all equipment is to be in accordance with the Rules for power and lighting circuits.

**1402** Cables are to be fitted in a similar manner to cables installed for lighting and power, but are to be segregated from the latter unless either the lighting and power cables or the communication cables are metal sheathed, or non-metallic impervious sheathed.

**1403** Communication circuits other than those supplied from primary batteries are to be protected against overload and short-circuit.

#### Passenger Alarms

**1404** In all passenger ships, except those engaged on short international voyages, electrically operated alarms, for summoning passengers to muster stations are to be fitted. They are to be operable from the bridge.

#### Steering Gear

**1405** Means of communication are to be fitted to enable orders to be transmitted from the bridge to the alternative steering station required by D 2307.

### Section 15

#### SEMI-CONDUCTOR RECTIFIERS FOR POWER

**1501** Rectifier stacks are to be so arranged that they may be removed from equipment without dismantling the complete unit.

**1502** Where forced cooling is provided the apparatus is to be so arranged that the rectifier cannot remain loaded unless effective cooling is maintained.

**1503** When necessary, means are to be provided to guard against d.c. voltage rise due to regenerated power.

**1504** When operated in parallel with other sources of d.c. power, load sharing is to be such that under normal conditions overloading of any unit does not occur and the combination of paralleled equipment is stable.

**1505** Fungus protection of the mercury type is not to be used in the vicinity of selenium rectifiers.

**1506** Monocrystalline rectifiers such as germanium and silicon are to be capable of withstanding the effects of transient over-voltages coming from the ship's network.

M 1402 - M 1602

### Section 16

#### SPECIAL REQUIREMENTS FOR TANKERS INTENDED FOR THE CARRIAGE IN BULK OF OIL, LIQUEFIED GAS AND OTHER FLAMMABLE LIQUIDS

The special requirements of this Section are divided into three parts related to the cargoes to be carried:—

Part 1. Tankers intended for the carriage in bulk of oil cargoes having a flash point below 60°C (closed cup test).

Paragraph Nos. 1621 to 1631.

Part 2. Tankers for the carriage of liquefied gases in bulk.

Paragraph Nos. 1641 to 1651.

Part 3. Tankers intended for the carriage in bulk of other flammable liquid cargoes.

Paragraph Nos. 1661 to 1664.

#### GENERAL REQUIREMENTS

##### Systems of Supply

**1601** The following systems of generation and distribution are acceptable:—

- d.c., two-wire insulated,
- a.c., single-phase, two-wire, insulated,
- a.c., three-phase, three-wire, insulated.

For high voltage generation and primary distribution (see M 18), a.c., three-phase, three-wire, neutral earthed is acceptable.

If the primary distribution system is extended to areas remote from the machinery space, isolating transformers or other means should be provided to prevent possible earth fault current from flowing through dangerous zones.

##### Distribution

**1602** No current carrying part of an insulated distribution system is to be earthed, other than through an earth indicating device or through components used for the suppression of radio interference, or as permitted by 1601.

Hull currents which may arise from the following are not considered to contravene this requirement:—

- (a) Sacrificial anode protective systems and impressed current cathodic protection systems for outer hull protection or for installations within the machinery space.
- (b) Limited and locally earthed systems, such as starting systems of oil engines.



**Fuses**

1603 Rewireable type fuses are not to be fitted.

**Earth Detection for Insulated Systems**

1604 A device(s) is to be installed to continuously monitor the insulation level, particularly of circuits (other than intrinsically safe circuits) which pass through dangerous zones or spaces or which are connected to apparatus installed in such zones or spaces.

The device(s) is to operate an alarm, at a recognized control position, in the event of an abnormally low level of insulation.

**Cables and Cable Installation**

1605 Electric cables are not to be installed in dangerous zones or spaces, except as permitted in certain paragraphs of this Section, or when associated with intrinsically safe circuits.

1606 All cables which may be exposed to cargo oil, oil vapour or gas are to be sheathed with at least one of the following:—

- (a) Copper sheath (for mineral insulated cable),
- (b) Lead alloy sheath plus further mechanical protection, e.g. armour or non-metallic impervious sheath,
- (c) Non-metallic impervious sheath plus armour (for mechanical protection and earth detection).

Where corrosion may be expected, non-metallic impervious sheath is to be applied over steel armour.

1607 Cables installed on deck or on fore and aft gangways are to be protected against mechanical damage. Cables are to be installed so as to avoid strain or chafing and due allowance made for expansion or working of the structure. Where expansion bends are fitted, they are to be accessible for maintenance.

Where cables pass through gastight bulkheads or decks, separating dangerous zones or spaces from non-dangerous zones or spaces, arrangements are to be such that the gastight integrity of the bulkhead or deck is not impaired.

1608 Cables installed in pump rooms are to be suitably protected against mechanical damage (*see also* 1624).

1609 Cables associated with intrinsically safe circuits are to be used only for such circuits. They are to be physically separated from cables associated with non-intrinsically safe circuits, e.g. neither led in the same casing or pipe nor secured by the same fixing clip.

**Control Circuits**

1610 Measuring, monitoring, control and telecommunication circuits located in dangerous zones or spaces are to be intrinsically safe.

**Transmitting Aerials**

1611 Transmitting aerials and any associated rigging should be sited well clear of gas and vapour outlets.

**Certified Safe Type Equipment**

1612 Where reference is made to the following "safe" types of equipment:—

- (a) Intrinsically safe (symbol i),
- (b) Flameproof (symbol d),
- (c) Increased safety (symbol e),
- (d) Pressurized enclosure (symbol p),

such equipment is to be certified for the gases and vapours involved. The construction and type testing is to be in accordance with IEC Publication 79, *Electrical Apparatus for Explosive Gas Atmospheres* or an equivalent National Standard.

In addition, lighting fittings of the air driven type with a pressurized enclosure are considered to be a "safe" type of lighting fitting.

When safe type equipment is permitted in dangerous zones or spaces, all switches and protective devices are to interrupt all lines or phases and are to be located in a non-dangerous zone or space unless specifically permitted otherwise.

Such equipment, switches and protective devices are to be suitably labelled for identification purposes.

**Dangerous Zones or Spaces**

1613 Dangerous zones or spaces are defined in other paragraphs of this Section, but the following general principles are to apply:—

- (a) Spaces containing flammable cargo and all zones or spaces adjacent to cargo tanks are regarded as dangerous zones or spaces.
- (b) An enclosed or semi-enclosed space with direct access into a dangerous zone or space is regarded as a dangerous space.
- (c) An enclosed space located in a dangerous zone or space may be regarded as a non-dangerous space, provided that it is separated from the flammable liquid cargo by not less than two gastight steel bulkheads or decks, is mechanically ventilated and, in addition, has no direct opening into a dangerous zone or space.



**Semi-enclosed Spaces**

**1614** Semi-enclosed spaces are considered to be spaces limited by decks and/or bulkheads in such a manner that the natural conditions of ventilation are sensibly different from those obtained on open deck, e.g. centre castle space.

**PART 1**

**TANKERS INTENDED FOR THE CARRIAGE IN BULK  
OF OIL CARGOES HAVING A FLASH POINT BELOW  
60°C (CLOSED CUP TEST)**

**1621** Paragraphs 1622 to 1631 define the dangerous zones or spaces and the electrical equipment permitted in such zones or spaces.

**1622 Cargo Tanks**

Intrinsically safe electrical equipment.

**1623 Cofferdams adjoining Cargo Tanks**

Intrinsically safe electrical equipment.

Electric depth-sounding devices hermetically enclosed, located clear of the cargo tank bulkhead, with cables installed in heavy gauge steel pipes with gastight joints up to the main deck.

Where impressed current cathodic protection systems are fitted (for external hull protection only), and if it is essential for the cables to pass through cofferdams, the cables are to be installed in heavy gauge steel pipes with gastight joints up to the main deck. Corrosion resistant pipes, providing adequate mechanical protection, are to be used in compartments which may be filled with sea water (e.g. permanent ballast tanks).

Where it is necessary for cables to pass through these spaces, other than those supplying the equipment described in this paragraph, they are to be installed in heavy gauge steel pipes with gastight joints.

**1624 Cargo Pump Rooms**

Electrical equipment as defined in 1623.

**Lighting.** Pump rooms immediately adjoining an engine room or similar non-dangerous space may be lit through permanently fitted glass lenses or ports fitted in the bulkhead or deck so arranged as to maintain integrity of the structure. The externally mounted lighting fixture may be designed so that the gastight flanged port forms part of the fixture. The lighting fixtures and wiring are to be located in the non-dangerous space.

Alternatively, flameproof lighting fittings (symbol d) may be fitted. The fittings are to be arranged on at least two independent final branch circuits to permit light from one circuit to be retained while maintenance is carried out on the other.

Lighting fittings of the air driven type, *see* 1612.

**Motors.** Electric motors driving equipment located in cargo pump rooms are to be separated from the pump room by a gastight bulkhead or deck. Flexible couplings or other means of maintaining alignment are to be fitted in the shafts between the motors and the driven unit. In addition, suitable stuffing boxes are to be fitted where shafts pass through gastight bulkheads or decks. *See* E 1112.

**Cables.** Where it is necessary for cables other than those supplying lighting to pass through cargo pump room entrances, they are to be installed in heavy gauge steel pipes with gastight joints.

**1625 Enclosed or semi-enclosed spaces immediately above cargo tanks or having bulkheads above and in line with cargo tank bulkheads**

Intrinsically safe equipment.

Safe type lighting fittings, *see* 1612.

Through runs of cable.

Electrical equipment other than the above may be installed in 'tween deck spaces, provided that such equipment is housed in a mechanically ventilated compartment having access solely from the deck above, and of which the floor is separated from the cargo tanks by a cofferdam and the boundaries are oiltight and gastight with respect to the cofferdam and the 'tween deck spaces.

**1626 Compartments for Cargo Hoses**

Intrinsically safe equipment.

Safe type lighting fittings, *see* 1612.

Through runs of cable.

**1627 Spaces other than cofferdams adjoining and below the top of a cargo tank, e.g. trunks, passageways and holds**

Intrinsically safe equipment.

Safe type lighting fittings, *see* 1612.

Through runs of cable.

Special consideration is to be given to the mechanical protection of electrical equipment in such spaces. *See also* D 4010.



**1628** Zones on open deck, within 3 m of any cargo oil tank outlet or vapour outlet, (e.g. cargo tank hatches; sight ports; tank cleaning openings; ullage openings; sounding pipes; cargo pump rooms and cofferdams; cargo pump room entrances)

Safe type equipment, *see* 1612. Such equipment is to be suitably protected for use on deck.

Through runs of cable; cable expansion bends are not to be in this zone.

**1629** Zones on open deck over all cargo tanks (including all ballast tanks within the cargo tank area) to the full width of the vessel, plus 3 m fore and aft on open deck, up to a height of 2,4 m above the deck

Safe type equipment, *see* 1612. Such equipment is to be suitably protected for use on deck.

Through runs of cable.

Where spillage barriers are fitted, the horizontal distance of the hazardous zone on open deck referred to above is deemed to extend 3 m aft of the spillage barrier or 3 m aft of the cargo tank area, whichever is further aft.

**1630** Dangerous zones above cargo tank vents and pressure/vacuum valves

The dangerous zone around and above the cargo tank vents and pressure/vacuum valves required by E 1117 to E 1132 is deemed to be a cylinder of 9 m radius (the radius being measured from the tank vent or pressure/vacuum valve) and of unlimited height.

If electrical equipment is fitted in this dangerous zone it is to be of safe type, *see* 1612.

**1631** Spaces forward of the cargo tanks and outside the dangerous zones previously described

Spaces forward of the cargo tanks below the level of the main deck, which have direct opening on to the main deck may become dangerous during certain wind conditions, even though the opening(s) is forward of the dangerous zone described in 1629.

Safe type equipment, *see* 1612, should be fitted in such spaces.

Alternatively, non-safe type equipment may be fitted in such spaces if self-closing air lock doors are provided for the opening on to the main deck and, in addition, mechanical ventilation is provided for the space; the air inlet is to be remote from any dangerous zone or space.

## PART 2

### TANKERS FOR THE CARRIAGE OF LIQUEFIED GASES IN BULK

#### General

**1641** Electrical arrangements are to comply with the relevant Sections of the *Rules and Regulations for the Construction and Classification of Ships for the Carriage of Liquefied Gases in Bulk* and with Chapter M of the *Rules and Regulations for the Construction and Classification of Steel Ships*.

#### Gas Dangerous Spaces and Zones

**1642** Paragraphs 1644 to 1651 define the gas dangerous spaces or zones and the electrical equipment permitted in such spaces or zones. *See also* Chapter III, paragraphs 3.5 and 3.6, of the *Rules for Ships for Liquefied Gases*.

#### 1643 Intrinsically Safe Equipment

Certified intrinsically safe circuits may be fitted in all gas dangerous spaces or zones.

#### 1644 Cargo Containment Systems and Piping

(*See* Chapter I of the *Rules for Ships for Liquefied Gases*.)

Submerged cargo pump motors and their supply cables may be fitted in cargo containment systems.

Means are to be provided to prevent the energizing of motors and cables when a gas/air mixture is present.

#### 1645 Hold Spaces where Cargo is Carried in a Cargo Containment System requiring a Secondary Barrier

(*See* Chapter I of the *Rules for Ships for Liquefied Gases*.)

Supply cables for submerged cargo pump motors.

#### 1646 Hold Spaces where Cargo is Carried in a Cargo Containment System not requiring a Secondary Barrier

(*See* Chapter I of the *Rules for Ships for Liquefied Gases*.)

Through runs of cable.

Lighting fittings with pressurized enclosure (symbol p) or flameproof enclosure (symbol d). The lighting system is to be arranged on at least two independent branch circuits to permit light from one circuit to be retained while maintenance is carried out on the other. All switches and protective devices are to interrupt all poles or phases and are to be located in a gas safe space.

Electrical depth sounding or log devices and impressed current cathodic protection system anodes or electrodes (external hull protection only). Such devices are to be housed in gastight enclosures.



**1647 Spaces Separated from the Hold Spaces described in 1645 by a Single Gastight Steel Boundary**

Equipment as permitted in 1646.

Flameproof (symbol d) motors for valve operation of cargo or ballast systems.

**1648 Cargo Pump Rooms and Cargo Compressor Rooms****(a) Lighting**

Lighting fittings with pressurized enclosure (symbol p) or flameproof enclosure (symbol d). The lighting system is to be arranged on at least two independent branch circuits. All switches and protective devices are to interrupt all poles or phases and are to be located in a gas safe space.

**(b) Motors**

- (i) Electric motors for driving cargo pumps or cargo compressors should be separated from the pump rooms or compressor rooms by a gastight bulkhead or deck. Flexible couplings or other means of maintaining alignment are to be fitted to the shafts between the driven equipment and its motors and, in addition, suitable glands are to be provided where the shafts pass through the gastight bulkhead or deck. Such electric motors and associated equipment are to be located in a compartment complying with Chapter XII of the *Rules for Ships for Liquefied Gases*.

- (ii) Where operational or structural requirements are such as to make it not possible to comply with the method described in (i), certified motors of the following types may be installed in cargo pump rooms or cargo compressor rooms:

Increased safety type (symbol e) with flameproof (symbol d) enclosure.

Pressurized type (symbol p).

**1649 Zones on Open Deck, or Semi-enclosed Spaces on Open Deck, within 3 m of any Cargo Tank Outlet, Gas or Vapour Outlet, Cargo Pipe Flange, Cargo Valves, Entrances and Ventilation Openings to Cargo Pump Rooms and Cargo Compressor Rooms**

Zones on Open Deck over the Cargo Area and 3 m Fore and Aft of the Cargo Area on the Open Deck and up to a height of 2,4 m above the Deck

**Zones within 2,4 m of the Outer Surface of a Cargo Containment System where such Surface is exposed to the Weather**

Through runs of cable

Certified safe type equipment

**1650 Enclosed or Semi-enclosed Spaces in which Pipes Containing Cargo Products are located****Compartments for Cargo Hoses**

(Spaces which contain gas detection equipment complying with paragraph 13.6.5 of the *Rules for Ships for Liquefied Gases*, and spaces utilizing boil-off gas as fuel and complying with Chapter XVI of the *Rules for Ships for Liquefied Gases*, are not considered gas dangerous spaces in this context.)

Through runs of cable

Lighting fittings with pressurized enclosure (symbol p) or flameproof enclosure (symbol d).

The lighting system is to be arranged on at least two independent branch circuits. All switches and protective devices are to interrupt all poles or phases and are to be located in a gas safe space.

**1651 Enclosed or Semi-enclosed Spaces having a Direct Opening into any Gas Dangerous Space or Zone**

Electrical equipment complying with the requirements for the space or zone into which the opening leads.

**PART 3****TANKERS INTENDED FOR THE CARRIAGE IN BULK OF OTHER FLAMMABLE LIQUID CARGOES**

**1661** For cargoes possessing flammable characteristics similar to those of oil products, the requirements are to be based on the closed cup test flash point and vapour pressure at ambient temperature.

For cargoes having a flash point below 60°C (closed cup test), either 1621 to 1631 or 1641 to 1651 are to be complied with where applicable.

This requirement is based on the assumption that there are no additional hazards due to chemical reaction.

**1662** For cargoes which, due to a very low flash point, a high vapour pressure, a wide flammability range coupled with a low lower explosive limit, or a very low auto-ignition temperature (i.e. Category 2, Table M 16.1), create a risk of fire or explosion greater than that for the cargoes considered



in 1661, and providing there are no additional hazards due to chemical reaction:—

The electrical installation is to be in accordance with 1622 to 1631, or 1642 to 1651, the appropriate type being determined by the closed cup test flash point and the vapour pressure at ambient temperature. In addition, the following are to apply:—

- (a) The extent of the hazardous zones described for open deck are to be increased from 3 m (or 2,4 m) to 4,5 m.
- (b) The inlets of ventilation systems for non-dangerous spaces should be at least 9 m from openings or ventilation outlets of any dangerous zone or space or from any gas or vapour outlet.
- (c) Special care is to be exercised in the selection of any safe type equipment, which may be installed

in any dangerous zones or spaces. Such equipment is to be specifically certified for use in the flammable gas or vapour involved.

**1663** For cargoes which, due to chemical instability or chemical reaction may generate flammable gases or vapours (i.e. Category 3, Table M 16.1):—

The electrical installation is to be in accordance with 1661 or 1662, the appropriate paragraph being determined by the characteristics of the cargo and of any generated gases or vapours and the rate of evolution.

**1664** Where the cargo is liable to damage materials normally used in the construction of electrical apparatus (Category 4, Table M 16.1), special consideration is to be given to the materials selected for conductors, insulation and metal parts and/or the protection thereof.

TABLE M 16.1

**QUALIFICATION OF LIQUID PRODUCTS WITH REGARD TO HAZARDS IN RESPECT OF ELECTRICAL INSTALLATIONS**

The hazard category is indicated by "x" in the Table.

- Category 1: Hazard levels similar to those encountered in the carriage of liquefied cargoes on board oil tankers and/or gas tankers, *see* 1661.
- Category 2: Hazard levels greater than Category 1, *see* 1662.
- Category 3: Hazard resulting from the possibility of generation of flammable gas or vapour (in particular, hydrogen) due to chemical reaction, *see* 1663.
- Category 4: Hazard due to deleterious effects on materials used in electrical equipment, e.g. aluminium, copper, rubber and elastomeric compounds, etc., *see* 1664.

## NOTES

1. The categories indicated concern hazards connected with the electrical installation only. Hazards due to toxicity, and due to chemical reaction other than those affecting electrical materials, have not been considered.
2. Products other than those indicated must be specially considered.
3. The list though not exhaustive is given for guidance.
4. Where practicable the enclosure grouping and temperature class (*see* IEC Publication 79-1, *Electrical Apparatus for Explosive Gas Atmospheres*) have been indicated. These may be subject to alteration as and when more precise information becomes available.



**TABLE M 16.1 TYPE A CARGOES** (see Chapter R(J))  
(see continuation)

NAME FORMULA	CATEGORY				SAFE TYPE EQUIPMENT AS IEC 79	
	1	2	3	4	GAS GROUP	TEMPERATURE CLASS
ACETIC ACID <chem>CH3COOH</chem>	x			x	IIA	T1
ACETIC ANHYDRIDE <chem>(CH3CO)2O</chem>	x			x	IIA	T2
ACETONE CYANOHYDRIN <chem>(CH3)2C(OH)CN</chem>				x	Not applicable	
ACETONITRILE <chem>CH3CN</chem>	x				IIA	T1
ACRYLIC ACID <chem>CH2H5CH2Cl</chem>	x			x		
ACRYLONITRILE <chem>CH2CHCN</chem>	x			x	IIB	T1
ALLYL ALCOHOL <chem>CH2CHCH2OH</chem>	x			x	IIB	T2
ALLYL CHLORIDE <chem>CH2CHCH2Cl</chem>	x			x	IIA	T2
ANILINE <chem>C6H5NH2</chem>				x	Not applicable	
BENZYL CHLORIDE <chem>C6H5CH2Cl</chem>				x	Not applicable	
n or iso-BUTYL ACRYLATE <chem>CH2CHCOOC4H9</chem>	x			x	IIB	
BUTYRIC ACID <chem>CH3CH2CH2COOH</chem>				x	Not applicable	
CARBOLIC OIL (containing naphthalene, phenol and cresols)					IIA	
2-CHLOROETHANOL <chem>ClCH2CH2OH</chem>	x			x	IIA	T2
CHLOROHYDRINS (crude)	x				IIA	
CHLOROSULPHONIC ACID <chem>ClSO2OH</chem>	x		x	x	IIA	
CROTONALDEHYDE <chem>CH3CHCHCHO</chem>	x			x	IIB	T3

**TABLE M 16.1 TYPE A CARGOES** (see Chapter R(J))  
(continued)

NAME FORMULA	CATEGORY				SAFE TYPE EQUIPMENT AS IEC 79	
	1	2	3	4	GAS GROUP	TEMPERATURE CLASS
1,2 DICHLOROPROPANE <chem>CH3CHClCH2Cl</chem>	x			x	IIA	T1
1,3 DICHLOROPROPENE <chem>CHClCHCH2Cl</chem>	x			x	IIA	
DIETHYL ETHER <chem>(C2H5)2O</chem>		x		x	IIB	T4
DIISOPROPYLAMINE <chem>((CH3)2CH)2NH</chem>	x			x		
1,4 DIOXANE <chem>CH2CH2OCH2CH2O</chem>	x				IIB	T2
EPICHLOROHYDRIN <chem>C3H5OCl</chem>	x				IIB	
ETHYLENE DIBROMIDE <chem>CH2BrCH2Br</chem>					Not applicable	
ETHYL ACRYLATE <chem>CH2CHCOOC2H5</chem>	x			x	IIB	
ETHYLENEDIAMINE <chem>NH2CH2CH2NH2</chem>	x			x	IIA	T2
ETHYLENE DICHLORIDE <chem>CH2ClCH2Cl</chem>	x				IIA	T2
FORMIC ACID <chem>HCOOH</chem>				x	Not applicable	
LACTIC ACID <chem>CH3CH(OH)COOH</chem>						
METHALLYL ALCOHOL <chem>CH2C(CH3)CH2OH</chem>	x					T2
METHYL ACRYLATE <chem>CH2CHCOOCH3</chem>	x				IIB	
METHYL METHACRYLATE <chem>CH2C(CH3)COOCH3</chem>	x			x	IIA	T2



TABLE M 16.1 TYPE A CARGOES (see Chapter R(J))  
(continued)

NAME FORMULA	CATEGORY				SAFE TYPE EQUIPMENT AS IEC 79	
	1	2	3	4	GAS GROUP	TEMPERATURE CLASS
NITRIC ACID (70% AQ. SOL. and OVER) $\text{HNO}_3$				x	Not applicable	
OLEUM $\text{H}_2\text{SO}_4 + \text{SO}_3$			x	x	Not applicable	
ORTHO-NITROTOLUENE $\text{CH}_3\text{C}_6\text{H}_4\text{NO}_2$					Not applicable	
PHENOL $\text{C}_6\text{H}_5\text{OH}$				x	Not applicable	
PHOSPHORIC ACID (85%) $\text{H}_3\text{PO}_4$				x	Not applicable	
PHOSPHORUS TRICHLORIDE $\text{PCl}_3$				x	Not applicable	
PHOSPHORYL CHLORIDE $\text{POCl}_3$				x	Not applicable	
B-PROPIOLACTONE $\text{OCH}_2\text{CH}_2\text{CO}$					Not applicable	
PROPIONIC ACID $\text{CH}_3\text{CH}_2\text{COOH}$	x			x	IIA	T1
PROPIONIC ANHYDRIDE $(\text{CH}_3\text{CH}_2\text{CO})_2\text{O}$	x					T3
n-PROPYLAMINE $\text{CH}_3\text{CH}_2\text{CH}_2\text{NH}_2$	x				IIA	T2
iso-PROPYLAMINE $(\text{CH}_3)_2\text{CHNH}_2$	x				IIA	T2
PROPYLENE OXIDE $\text{CH}_3\text{CHCH}_2\text{O}$		x		x	IIB	T2
SULPHURIC ACID $\text{H}_2\text{SO}_4$			x	x	Not applicable	
TOLYLENE DI-ISOCYANATE $\text{CH}_3\text{C}_6\text{H}_3(\text{NCO})_2$				x	Not applicable	

**TABLE M 16.1 TYPE A CARGOES** (see Chapter R(J))  
(conclusion)

[illegible]



TABLE M 16.1 TYPE B CARGOES (see Chapter R(J))

(see continuation)

NAME FORMULA	CATEGORY				SAFE TYPE EQUIPMENT AS IEC 79	
	1	2	3	4	GAS GROUP	TEMPERATURE CLASS
ADIPONITRILE $\text{CN}(\text{CH}_2)_4\text{CN}$				x	Not applicable	
AMMONIA 30% SOL. $\text{NH}_4\text{OH}$	x			x	IIA	T1
BENZENE $\text{C}_6\text{H}_6$	x				IIA	T1
iso-BUTYRALDEHYDE $(\text{CH}_3)_2\text{CHCHO}$	x				IIA	T3
n-BUTYRALDEHYDE $\text{CH}_3(\text{CH}_2)_2\text{CHO}$	x				IIA	T3
CAPROLACTAM SOL. $\text{CH}_2(\text{CH}_2)_4\text{NHCO}$						
CARBON TETRACHLORIDE $\text{CCl}_4$				x	Not applicable	
CHLOROBENZENE $\text{C}_6\text{H}_5\text{Cl}$	x			x	IIA	T1
CHLOROFORM $\text{CHCl}_3$					Not applicable	
CRESOLS (CRESYLIC ACID) (mixed isomers) $\text{CH}_3\text{C}_6\text{H}_4\text{OH}$				x	Not applicable	
CUMENE $\text{C}_6\text{H}_5\text{CH}(\text{CH}_3)_2$	x			x	IIA	T2
CREOSOTE				x	Not applicable	
CYCLOHEXYLAMINE $\text{C}_6\text{H}_{11}\text{NH}_2$	x			x	IIA	T3
2,2 DICHLOROETHYL ETHER $\text{ClCH}_2\text{CH}_2\text{OCH}_2\text{CH}_2\text{Cl}$	x			x	IIA	T2
DIETHANOLAMINE $(\text{HOCH}_2\text{CH}_2)_2\text{NH}$				x	Not applicable	
DIETHYLAMINE $(\text{C}_2\text{H}_5)_2\text{NH}$	x			x	IIA	T2

TABLE M 16.1 TYPE B CARGOES (see Chapter R(J))

(continued)

NAME FORMULA	CATEGORY				SAFE TYPE EQUIPMENT AS IEC 79	
	1	2	3	4	GAS GROUP	TEMPERATURE CLASS
DIETHYLENE TRIAMINE $\text{NH}_2\text{CH}_2\text{CH}_2\text{NHCH}_2\text{CH}_2\text{NH}_2$				x	Not applicable	
DIMETHYLAMINE 40% AQ. $(\text{CH}_3)_2\text{NH}$		x		x	IIA	T2
DIMETHYLAMINOETHANOL $(\text{CH}_3)_2\text{NCH}_2\text{CH}_2\text{OH}$	x			x	IIA	
DIMETHYL FORMAMIDE $\text{HCON}(\text{CH}_3)_2$	x			x	IIA	T2
DODECYLPHENOL $\text{C}_{12}\text{H}_{25}\text{C}_6\text{H}_4\text{OH}$				x	Not applicable	
2 ETHYL 3 PROPYL ACROLEIN $\text{CH}_3(\text{CH}_2)_2\text{CHC}(\text{C}_2\text{H}_5)\text{CHO}$					Not applicable	
ETHYLENE CYANOHYDRIN $\text{CH}_2\text{OHCH}_2\text{CN}$					Not applicable	
FORMALDEHYDE SOL. 37% $\text{HCHO}$	x			x	IIB	T2
FURFURAL $\text{C}_4\text{H}_3\text{OCHO}$	x			x	IIA	T2
FURFURYL ALCOHOL $\text{C}_4\text{H}_3\text{OCH}_2\text{OH}$					Not applicable	
ISOPRENE $\text{CH}_2 : \text{C}(\text{CH}_3)\text{CH} : \text{CH}_2$	x				IIB	T3
MESITYL OXIDE $(\text{CH}_3)_2\text{C} : \text{CHCOCH}_3$	x				IIA	T2
METHYLENE CHLORIDE $\text{CH}_2\text{Cl}_2$	x			x	IIA	T1
$\alpha$ METHYL STYRENE $\text{C}_6\text{H}_5\text{C}(\text{CH}_3) : \text{CH}_2$	x					T1
MORPHOLINE $(\text{CH}_2)_4\text{ONH}$	x			x	IIA	T2



TABLE M 16.1 TYPE B CARGOES (see Chapter R(J))

(conclusion)

NAME FORMULA	CATEGORY				SAFE TYPE EQUIPMENT AS IEC 79	
	1	2	3	4	GAS GROUP	TEMPERATURE CLASS
NAPHTHENIC ACIDS				x	Not applicable	
NITROBENZENE $C_6H_5NO_2$					Not applicable	
PENTACHLOROETHANE $CHCl_2CCl_3$				x	Not applicable	
PROPIONALDEHYDE $C_2H_5CHO$	x				IIB	T3
PYRIDINE (99% conc.) $N(CH)_4CH$	x			x	IIA	T1
SODIUM HYPOCHLORITE 15% SOL. $NaOCl$			x	x	Not applicable	
STYRENE MONOMER $C_6H_5CHCH_2$	x					
TETRACHLOROETHANE $CHCl_2CHCl_2$				x	Not applicable	
TETRAHYDROFURAN $(C_2H_4)_2O$	x				IIB	T2
TRIETHYLENE TETRAMINE $NH_2(C_2H_4NH)_3H$				x	Not applicable	
iso-VALERALDEHYDE $(CH_3)_2CHCH_2CHO$	x				IIB	
n-VALERALDEHYDE $CH_3(CH_2)_3CHO$	x				IIB	

TABLE M 16.1 TYPE C CARGOES (see Chapter R(J))

(see continuation)

NAME FORMULA	CATEGORY				SAFE TYPE EQUIPMENT AS IEC 79	
	1	2	3	4	GAS GROUP	TEMPERATURE CLASS
ACETONE $\text{CH}_3\text{COCH}_3$	x			x	IIA	T1
ALPHANOL				x	Not applicable	
AMINOETHYL ETHANOLAMINE $\text{NH}_2(\text{CH}_2)_2\text{NH}(\text{CH}_2)_2\text{OH}$				x	Not applicable	
AMYL ACETATE-iso $\text{CH}_3\text{COO}(\text{CH}_2)_2\text{CH}(\text{CH}_3)_2$	x			x	IIA	T2
AMYL ACETATE-sec $\text{CH}_3\text{COOCH}(\text{CH}_3)\text{C}_3\text{H}_7$	x			x	IIA	
AMYL ACETATE-n $\text{CH}_3\text{COOC}_5\text{H}_{11}$	x			x	IIA	T2
AMYL ALCOHOL-n $\text{CH}_3(\text{CH}_2)_4\text{OH}$	x				IIA	T2
AMYL ALCOHOL-p, iso $(\text{CH}_3)_2\text{CHCH}_2\text{CH}_2\text{OH}$	x				IIA	T2
AMYL ALCOHOL-sec, n $(\text{CH}_3\text{CH}_2)_2\text{CHOH}$	x				IIA	T2
AMYL ALCOHOL-sec, iso $(\text{CH}_3)_2\text{CHCHOHCH}_3$	x				IIA	
AMYL ALCOHOL-tert $(\text{CH}_3)_2\text{C}_2\text{H}_5\text{COH}$	x				IIA	T2
AROMASOL-H	x			x	IIA	T1
ASPHALT						
BENZYL ALCOHOL $\text{C}_6\text{H}_5\text{CH}_2\text{OH}$				x	Not applicable	
BUTYL ACETATE-iso $\text{CH}_3\text{COOCH}_2\text{CH}(\text{CH}_3)_2$	x			x	IIA	T2
BUTYL ACETATE-n $\text{CH}_3\text{COOC}_4\text{H}_9$	x			x	IIA	T2
BUTYL ACETATE-sec $\text{CH}_3\text{COOCH}(\text{CH}_3)(\text{C}_2\text{H}_5)$	x			x	IIA	T1
BUTYL ALCOHOL-iso $(\text{CH}_3)_2\text{CHCH}_2\text{OH}$	x				IIA	T2



TABLE M 16.1 TYPE C CARGOES (see Chapter R(J))

(continued)

NAME FORMULA	CATEGORY				SAFE TYPE EQUIPMENT AS IEC 79	
	1	2	3	4	GAS GROUP	TEMPERATURE CLASS
BUTYL ALCOHOL-n $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH}$	x				IIA	T2
BUTYL ALCOHOL-sec $\text{CH}_3\text{CH}_2\text{CHOHCH}_3$	x				IIA	T2
BUTYL ALCOHOL-tert $(\text{CH}_3)_2\text{COHCH}_3$	x				IIA	T1
BUTYL BENZYL PHTHALATE $\text{C}_4\text{H}_9\text{COOC}_6\text{H}_4\text{COOCH}_2\text{C}_6\text{H}_5$				x	Not applicable	
BUTYL DIGLYCOL ACETATE $\text{C}_4\text{H}_9\text{O}(\text{CH}_2)_2\text{O}(\text{CH}_2)_2\text{OCOCH}_3$				x	Not applicable	
BUTYL ETHER $(\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2)_2\text{O}$	x			x	IIB	
BUTYLENE GLYCOL (S)					Not applicable	
BUTYL METHACRYLATE $\text{CH}_2\text{C}(\text{CH}_3)\text{COOC}_4\text{H}_9$	x			x	IIA	
BUTYL PHTHALATE $\text{C}_6\text{H}_4(\text{COOC}_4\text{H}_9)_2$				x	Not applicable	
CAMPHOR OIL				x	Not applicable	
CARADOL (S)				x	Not applicable	
CAUSTIC POTASH 50% SOL. KOH			x	x	Not applicable	
CAUSTIC SODA 55% NaOH			x	x	Not applicable	
CYCLOHEPTANE $\text{C}_7\text{H}_{14}$	x				IIA	
CYCLOHEXANE $\text{C}_6\text{H}_{12}$	x				IIA	T3
CYCLOHEXANOL $\text{C}_6\text{H}_{11}\text{OH}$					Not applicable	
CYCLOHEXANONE $\text{C}_6\text{H}_{10}\text{O}$	x			x	IIA	T2
p-CYMENE $\text{CH}_3\text{C}_6\text{H}_4\text{CH}(\text{CH}_3)_2$	x				IIA	T2

TABLE M 16.1 TYPE C CARGOES (see Chapter R(J))

(continued)

NAME FORMULA	CATEGORY				SAFE TYPE EQUIPMENT AS IEC 79	
	1	2	3	4	GAS GROUP	TEMPERATURE CLASS
n-DECYL ALCOHOL $\text{CH}_3(\text{CH}_2)_8\text{CH}_2\text{OH}$					Not applicable	
iso-DECYL ALCOHOL $\text{C}_{10}\text{H}_{21}\text{OH}$	x			x	IIA	
DECYL ACRYLATE-iso				x	Not applicable	
DIACETONE ALCOHOL $\text{CH}_3\text{COCH}_2\text{C}(\text{CH}_3)_2\text{OH}$	x			x	IIA	T1
DIBUTYLAMINE $(\text{C}_4\text{H}_9)_2\text{NH}$	x			x	IIA	
DIBUTYL PHTHALATE $\text{C}_6\text{H}_4(\text{COOC}_4\text{H}_9)_2$				x	Not applicable	
DIETHYL PHTHALATE $\text{C}_6\text{H}_4(\text{COOC}_2\text{H}_5)_2$				x	Not applicable	
1,2 DICHLOROBENZENE $\text{C}_6\text{H}_4\text{Cl}_2$				x	Not applicable	
DICYCLOPENTADIENE $\text{C}_{10}\text{H}_{12}$	x			x	IIA	T3
DIETHYLBENZENE $\text{C}_6\text{H}_4(\text{C}_2\text{H}_5)_2$	x				IIA	T2
DIETHYLENE GLYCOL $\text{CH}_2\text{OHCH}_2\text{OCH}_2\text{CH}_2\text{OH}$					Not applicable	
DIETHYLENE GLYCOL METHYL ETHER $\text{CH}_3\text{OCH}_2\text{CH}_2\text{OCH}_2\text{CH}_2\text{OH}$					Not applicable	
DIETHYLENE GLYCOL MONOBUTYL ETHER $\text{C}_4\text{H}_9\text{OCH}_2\text{CH}_2\text{OCH}_2\text{CH}_2\text{OH}$					Not applicable	
DIETHYLENE GLYCOL MONOETHYL ETHER $\text{CH}_3\text{CH}_2\text{OCH}_2\text{CH}_2\text{OCH}_2\text{CH}_2\text{OH}$					Not applicable	
DIISOBUTYLENE Compound of $\text{C}_8\text{H}_{16}$	x			x		
DIISOPROPANOLAMINE $(\text{CH}_3\text{CHOHCH}_2)_2\text{NH}$				x	Not applicable	
DIISOBUTYLKETONE $((\text{CH}_3)_2\text{CHCH}_2)_2\text{CO}$	x			x	IIA	T2
DIISOCTYL PHTHALATE $\text{C}_6\text{H}_4(\text{COOC}_8\text{H}_{17})_2$				x		



**TABLE M 16.1 TYPE C CARGOES** (see Chapter R(J))  
(continued)

NAME FORMULA	CATEGORY				SAFE TYPE EQUIPMENT AS IEC 79	
	1	2	3	4	GAS GROUP	TEMPERATURE CLASS
DIMETHYL PHTHALATE $C_6H_4(COOCH_3)_2$				x	Not applicable	
DIOCTYL PHTHALATE $C_6H_4(COOC_8H_{17})_2$				x	Not applicable	
DIPENTENE $C_{10}H_{16}$	x				IIA	T3
DIPHENYL OXIDE $(C_6H_5)_2O$					Not applicable	
DIPROPYLENE GLYCOL $(CH_3CHOHCH_2)_2O$					Not applicable	
DIPROPYLENE GLYCOL METHYL ETHER $CH_3OC_3H_6OC_3H_6OH$					Not applicable	
DOBANOL				x	Not applicable	
DODECYL ALCOHOL $CH_3(CH_2)_{11}OH$				x	Not applicable	
DODECYL BENZENE $C_{12}H_{25}C_6H_5$				x	Not applicable	
DUTREX					Not applicable	
ETHYL ACETATE $CH_3COOC_2H_5$	x			x	IIA	T1
ETHYL ALCOHOL $C_2H_5OH$	x				IIA	T2
ETHYL BENZENE $C_6H_5C_2H_5$	x			x	IIA	T2
ETHYL CYCLOHEXANE $C_2H_5C_6H_{11}$	x				IIA	T3
2-ETHYL HEXYL ACRYLATE $CH_2CHCO_2CH_2CH(C_2H_5)C_4H_9$				x	Not applicable	
ETHYLENE CARBONATE $(CH_2O)_2CO$					Not applicable	
ETHYLENE GLYCOL $CH_2OHCH_2OH$					Not applicable	

TABLE M 16.1 TYPE C CARGOES (see Chapter R(J))

(continued)

NAME FORMULA	CATEGORY				SAFE TYPE EQUIPMENT AS IEC 79	
	1	2	3	4	GAS GROUP	TEMPERATURE CLASS
ETHYLENE GLYCOL MONOBUTYL ETHER $C_4H_9OCH_2CH_2OH$				x	Not applicable	
ETHYLENE GLYCOL MONOBUTYL ETHER ACETATE $C_4H_9O(CH_2)_2OOCCH_3$				x	Not applicable	
ETHYLENE GLYCOL MONOETHYL ETHER $CH_2OHCH_2OC_2H_5$	x			x	IIA	T3
ETHYLENE GLYCOL MONOETHYL ETHER ACETATE $CH_3COOCH_2CH_2OC_2H_5$	x			x	IIA	T2
ETHYLENE GLYCOL MONOMETHYL ETHER $CH_3OCH_2CH_2OH$	x			x	IIB	T3
ETHYLENE GLYCOL MONOPHENYL ETHER $C_6H_5O(CH_2)_2OH$					Not applicable	
2-ETHYL HEXANOL $CH_3(CH_2)_3CHC_2H_5CH_2OH$					Not applicable	
GLYCERINE (GLYCEROL) $C_3H_5(OH)_3$					Not applicable	
HEPTANE-n $CH_3(CH_2)_5CH_3$	x				IIA	T3
HEPTENE (MIXED ISOMERS) $C_7H_{14}$	x				IIA	T3
HEPTYL ALCOHOL-iso $C_7H_{15}OH$					Not applicable	
HEPTYL ALCOHOL-n $CH_3(CH_2)_5CH_2OH$					Not applicable	
HEXANE-iso $CH_3(CH_2)_2CH(CH_3)_2$	x				IIA	
HEXENE-1 $CH_2CH(CH_2)_3CH_3$	x				IIA	T3
HEXYL ALCOHOL-n $CH_3(CH_2)_4CH_2OH$					Not applicable	



TABLE M 16.1 TYPE C CARGOES (see Chapter R(J))  
(continued)

NAME FORMULA	CATEGORY				SAFE TYPE EQUIPMENT AS IEC 79	
	1	2	3	4	GAS GROUP	TEMPERATURE CLASS
HEXYLENE GLYCOL $(\text{CH}_3)_2\text{COHCH}_2\text{CHOHCH}_3$					Not applicable	
METHYL ACETATE $\text{CH}_3\text{COOCH}_3$	x				IIA	T1
METHYL ALCOHOL $\text{CH}_3\text{OH}$	x				IIA	T1
METHOXYTRIGLYCOL $\text{CH}_3\text{O}(\text{C}_2\text{H}_4\text{O})_3\text{H}$					Not applicable	
METHYL AMYL ACETATE $\text{CH}_3\text{COOCH}(\text{CH}_3)\text{CH}_2\text{CH}(\text{CH}_3)_2$	x			x	IIA	
METHYL AMYL ALCOHOL $(\text{CH}_3)_2\text{CHCH}_2\text{CH}(\text{CH}_3)\text{OH}$	x			x	IIA	
METHYL ETHYL KETONE $\text{CH}_3\text{COC}_2\text{H}_5$	x			x	IIA	T1
METHYL ISOBUTYL KETONE $\text{CH}_3\text{COCH}_2\text{CH}(\text{CH}_3)_2$	x			x	IIA	T1
MONOETHANOLAMINE $\text{HOCH}_2\text{CH}_2\text{NH}_2$				x	Not applicable	
2-METHYL 5-ETHYL PYRIDINE $\text{CH}_3\text{C}_5\text{H}_3\text{NC}_2\text{H}_5$				x	Not applicable	
MONOISOPROPANOLAMINE $\text{CH}_3\text{CHOHCH}_2\text{NH}_2$				x	Not applicable	
NAPHTHA (PETROLEUM)	x				IIA	T3
NAPHTHA (SOLVENT) (COAL TAR)	x			x	IIA	T3
NAPHTHALENE (MOLTEN) $\text{C}_{10}\text{H}_8$					Not applicable	
NIAX POLYOL					Not applicable	
NITROETHANE $\text{CH}_3\text{CH}_2\text{NO}_2$	x			x	IIB	T2
NITROMETHANE $\text{CH}_3\text{NO}_2$	x				IIA	T2

TABLE M 16.1 TYPE C CARGOES (see Chapter R(J))

(continued)

NAME FORMULA	CATEGORY				SAFE TYPE EQUIPMENT AS IEC 79	
	1	2	3	4	GAS GROUP	TEMPERATURE CLASS
NITROPROPANE-1 $\text{CH}_3\text{CH}_2\text{CH}_2\text{NO}_2$	x			x	IIB	T2
NITROPROPANE-2 $(\text{CH}_3)_2\text{CHNO}_2$	x			x	IIB	T2
NONANE-n $\text{C}_9\text{H}_{20}$	x				IIA	T3
i-NONENE (NONYLENE) $\text{C}_9\text{H}_{18}$	x				IIA	
NONYL ALCOHOL $\text{C}_9\text{H}_{19}\text{OH}$					Not applicable	
NONYL PHENOL $\text{C}_9\text{H}_{19}\text{C}_6\text{H}_4\text{OH}$					Not applicable	
iso-OCTANE $\text{C}_8\text{H}_{18}$	x				IIA	T2
OCTENE $\text{C}_8\text{H}_{16}$	x				IIA	
OCTYL ALCOHOL $\text{CH}_3(\text{CH}_2)_7\text{CH}_2\text{OH}$					Not applicable	
OLEFINS	x					
PERCHLOROETHYLENE $\text{C}_2\text{Cl}_4$					Not applicable	
iso-PHORONE $\text{COCH} : \text{C}(\text{CH}_3)\text{CH}_2\text{C}(\text{CH}_3)\text{CH}_2$				x	Not applicable	
POTASSIUM HYDROXIDE 50% KOH			x	x	Not applicable	
PROPYL ACETATE-i $\text{CH}_3\text{COOCH}(\text{CH}_3)_2$	x			x	IIA	T1
PROPYL ACETATE-n $\text{CH}_3\text{OCC}_3\text{H}_7$	x			x	IIA	T2
PROPYL ALCOHOL-i $(\text{CH}_3)_2\text{CHOH}$	x				IIA	T2
PROPYL ALCOHOL-n $\text{C}_3\text{H}_7\text{OH}$	x				IIA	T2



TABLE M 16.1 TYPE C CARGOES (see Chapter R(J))

(continued)

NAME FORMULA	CATEGORY				SAFE TYPE EQUIPMENT AS IEC 79	
	1	2	3	4	GAS GROUP	TEMPERATURE CLASS
PROPYLENE GLYCOL $\text{CH}_3\text{CHOHCH}_2\text{OH}$					Not applicable	
PROPYLENE GLYCOL MONOMETHYL ETHER $\text{CH}_3\text{OCH}_2\text{CHOHCH}_3$	x			x	IIA	
SHELL SOLS	x			x		
SOLVESSO 100	x			x	IIA	T1
SOLVESSO 150				x	Not applicable	
TEEPOLS					Not applicable	
TETRAHYDRONAPHTHALENE $\text{C}_{10}\text{H}_{12}$					Not applicable	
TETRAPROPYLENE $\text{C}_{12}\text{H}_{24}$					Not applicable	
TOLUENE $\text{C}_6\text{H}_5\text{CH}_3$	x			x	IIA	T1
TRICHLOROETHANE 1, 1, 1 $\text{CH}_3\text{CCl}_3$				x		
TRICHLOROETHYLENE $\text{C}_2\text{HCl}_3$	x			x	IIA	T2
TRIDECYL ALCOHOL $\text{C}_{12}\text{H}_{25}\text{CH}_2\text{OH}$				x	Not applicable	
TRIETHANOLAMINE $(\text{HOC}_2\text{H}_4)_3\text{N}$				x	Not applicable	
TRIETHYL BENZENE $\text{C}_6\text{H}_3(\text{CH}_2\text{CH}_3)_3$				x	Not applicable	
TRIETHYLENE GLYCOL $\text{C}_6\text{H}_{14}\text{OH}$					Not applicable	
TRIPROPYLENE $\text{C}_9\text{H}_{18}$	x				IIA	

TABLE M 16.1 TYPE C CARGOES (see Chapter R(J))  
(conclusion)

NAME FORMULA	CATEGORY				SAFE TYPE EQUIPMENT AS IEC 79	
	1	2	3	4	GAS GROUP	TEMPERATURE CLASS
TRIPROPYLENE GLYCOL $C_9H_{20}O_4$					Not applicable	
TRIPROPYLENE GLYCOL MONOMETHYL ETHER $HO(C_3H_6O)_2C_3H_6OCH_3$					Not applicable	
TURPENTINE	x			x		T3
VINYL ACETATE $CH_3COOCHCH_2$	x				IIA	T2
VINYL TOLUENE $CH_2CHC_6H_4CH_3$	x				IIA	
WHITE SPIRIT	x			x	IIA	T3
XYLENE-m $C_6H_4(CH_3)_2$	x				IIA	T1
XYLENE-o $C_6H_4(CH_3)_2$	x				IIA	T1
XYLENE-p $C_6H_4(CH_3)_2$	x				IIA	T1
XYLENOL 3,5 $(CH_3)_2C_6H_3OH$						



**Section 17****ELECTRIC PROPELLING MACHINERY****General**

1701 All electric propelling machinery including switchgear, control gear, cables, main and auxiliary generators, motors and exciters is to comply with the relevant Sections of the Rules and is to be constructed under special survey.

1702 Prime movers are to comply with the relevant Sections of Chapter H.

1703 Armature shafts and other important steel forgings and castings are to comply with the requirements of Chapter Q.

1704 The torsional vibration characteristics of the propulsion system are to be submitted as required by H 241 to H 243 as applicable.

1705 Cooling water and lubricating oil systems are to comply with E 8 and E 9 where applicable.

**General Arrangements**

1706 Where the arrangements permit a propulsion motor to be connected to generating plant having a continuous rating greater than the motor rating, means are to be provided to limit the continuous input to the motor to a value not exceeding the continuous full load torque for which the motor and shafts are approved.

1707 Motors and generators of 400 kW or over are to be provided with means for heating the windings to prevent condensation when idle. If steam pipes are used for this purpose the joints are not to be within the machine.

**Excitation**

1708 Systems dependent on the auxiliary generators for excitation are to be capable of manoeuvring and of maintaining power at all times with a fall of 10 per cent excitation voltage at the busbars.

Where motor driven exciters, boosters, balancers or rectifiers are provided for excitation purposes, provision for an alternative supply of excitation is to be made. Where two machines are used each of at least 50 per cent of the required power it will be sufficient to provide one spare machine.

1709 Negative boosters are to be provided with overspeed protection, where necessary.

1710 In d.c. constant pressure systems arrangements for generator and motor excitation are to be such that if the motor excitation circuit is opened by a switch or contactor the generator excitation is simultaneously interrupted or the generator voltage is immediately reduced to zero.

1711 VOLTAGES—No voltage limitations are specified.

**Manoeuvring Controls**

1712 When two or more control stations are provided indicating lights are to be located at each control to indicate which station is in control.

1713 Where bridge or deck control is employed alternative control in the engine room is to be provided.

1714 Suitable interlocks, operating preferably by mechanical means are to be provided to prevent damage to the plant as a result of incorrect switching, such as the opening of switches or contactors not intended to be operated while carrying current.

1715 Provision is to be made for the manual operation without undue manual effort, of all manoeuvring contactors, switches, field regulators and controllers. Where electric, pneumatic or hydraulic aid is used for normal operation, failure of such aid is not to result in interruption of power to the propeller shaft and any such device is to be capable of purely manual operation without delay. This latter requirement does not apply to bridge control equipment.

Alternative arrangements will be specially considered.

**Cables**

1716 Conductors in circuits essential for manoeuvring or maintenance of propelling power are to be stranded having not less than seven strands and shall have a nominal cross-sectional area of not less than 2,5 mm<sup>2</sup>.

1717 Cables which are connected to the slip rings of synchronous motors are to be suitably insulated for the voltage to which they are subjected during manoeuvring.

1718 All joints are to be so made as to inhibit corrosion. They are to be arranged and supported in a manner suitable for withstanding the electro-mechanical forces due to short-circuit.

**Overload and Short-circuit Protection**

1719 Provision is to be made for protection against severe overloads, and electrical faults likely to result in damage to the plant.



**Earth Leakage Detection**

1720 The main propulsion circuit is to be provided with means for detecting earth faults. For direct current equipments exceeding 500 V and for all alternating current equipments, aural and visual alarms are to be automatically operated on the occurrence of an earth fault, but the operation of such devices is not to interrupt the power supply. A switch may be provided to switch off the aural device, but in such cases the visual alarm shall remain switched on to indicate that the aural device is switched off. Alternative arrangements will be specially considered. If an earth connection is used for operating the detector arrangements then in direct current systems the earth circuit is to be automatically opened in order to stop the circulation of fault current. In alternating current systems the fault current is to be interrupted or limited to a safe value.

1721 Earth leakage devices are to be arranged to function for all earth faults exceeding 5 amp. In three-phase star connected alternating current generators and motors with neutral points earthed, the earth leakage device shall operate on the occurrence of an earth fault in the windings of the machine, subject to the provision that 5 per cent of the coils at the neutral end of each phase may be left unprotected by the device. In high voltage a.c. systems where the capacitive leakage current is high consideration will be given to increasing this figure of 5 per cent.

1722 Excitation circuits are to be provided with lamps, voltmeters or other means to indicate continuously the state of the insulation of the excitation circuits under running conditions.

**Discharge Protection**

1723 For the protection of field windings and cables, means are to be provided for limiting the induced voltage when the field circuits are opened, or alternatively, the induced voltage, when the field circuits are opened, is to be taken at the nominal design voltage.

1724 Where excitation is obtained from the auxiliary busbars means are to be provided to limit the voltage induced at the busbars when the auxiliary circuit-breaker or the distribution circuit-breaker opens.

1725 Shunt resistors which are connected across the field circuit of synchronous propulsion motors when they are functioning as asynchronous motors are to be suitably insulated for the voltage induced when reversing and are to be amply rated to allow for inadvertent delay during the reversing operation.

**Safety Devices**

1726 Where separately driven direct current generators are connected electrically in series means are to be provided to prevent reversal of the direction of rotation of any of them on the failure of the prime mover.

1727 Where, on stopping or reversing the propeller, the regenerated energy transmitted by the propulsion motor is such as to cause a dangerous increase of speed in the prime mover, means are to be provided for suitably absorbing or limiting such energy.

1728 Contactors and switches used for reversing the rotation of the propulsion motors are to be provided with means for forcibly opening them if they should inadvertently remain closed, and they are to be so interlocked as to prevent the circuits for ahead and astern being closed simultaneously.

**Alarms**

1729 An aural alarm device is to be provided for machines having enclosed ventilating systems, arranged to operate in the event of the temperature of the heated air exceeding the predetermined safe value.

**Identification**

1730 All important circuits, instruments and apparatus are to be clearly labelled for identification.

**Section 18****SPECIAL REQUIREMENTS FOR HIGH VOLTAGE SYSTEMS (see M 203)**

NOTE. High voltage refers to a marine electrical supply system operating at a voltage in excess of ~~1000~~ V, 3-phase, a.c. Notice No.

**Introduction**

1801 High voltage generation and distribution may be considered appropriate when:—

(a) The system fault power under normal operating conditions exceeds 50 MVA.

(b) The capacity of individual generating sets is in excess of 2500 kW.

**Generation and Distribution**

1802 Arrangements are to be made so that it is possible to split the main high voltage switchboard into at least two independent sections, each supplied by at least one generator. ~~The switchboard sections should preferably be located in separate compartments.~~

DELETED PER NOTICE No.



1803 The distribution system is to be such that essential services which are duplicated are supplied from separate sections of the switchboard.

#### Insulated Neutral Systems

1804 For insulated neutral systems special consideration is to be given to the dielectric strength of all high voltage equipment.

1805 In order to preserve the same standard of insulation as with 500 V equipment and to guard against over-voltages which may arise with the insulated neutral system, the test voltage during the high voltage test is to be not less than 7.5 times line to neutral voltage and is to be applied for not less than one minute.

For rotating machinery this extra high voltage test may be replaced by:—

- (a) An interturn test on a sample coil
- and (b) The normal high voltage test carried out on the completed machine (see M 428).

The interturn test, between adjacent turns which are not connected in parallel, is to be a type test on the particular insulation system used. The test is to be taken between any adjacent effective turns where the greatest voltage is expected in service. The test is to be made on a coil in the fully processed condition, as it would be in the finished winding and the method of making the test and its duration is to be as in M 428 but preferably at the frequency of the ship's system.

The magnitude of the test withstand voltage is to be as given in Table M 18.1.

TABLE M 18.1

TYPE OF COIL	INTERTURN TEST VOLTAGE
Single stack coils ... ..	$\frac{V}{3} + 1000$
Multi stack coils where adjacent conductors in the width stack are connected in parallel ... ..	$\frac{V}{3} + 1000$
Multi stack coils with zig-zag series connections ... ..	$\frac{2V}{3} + 1000$
Multi stack coils with up/down series connections ... ..	$V + 1000$

Where  $V$  = System line voltage of the supply for which the coil is designed.

#### Earthed Neutral Systems

1806 When the earthed neutral system of generation and distribution is used, earthing is to be through a resistor. The resistor is to be such that earth fault current is limited to a value which is not greater than full load current of the largest generator on a switchboard section nor less than three times the minimum current required to operate any device protecting against earth faults.

1807 The high voltage test for equipment in an earthed neutral system is to be as required for medium voltage equipment in other Sections of this Chapter.

1808 Generator neutrals may be connected in common provided that the third harmonic content of the waveform of each generator does not exceed 5 per cent.

1809 Where a switchboard is split into sections operated independently or where there are separate switchboards, an earthing resistor is to be provided for each section or for each switchboard.

Means are to be provided to ensure that the earth connection is not removed when generators are isolated.

1810 A means of isolation is to be fitted in the earthing connection of each generator so that generators can be completely isolated for maintenance.

1811 All earthing resistors are to be connected to the hull. In order to eliminate possible interference with radio, radar and communication circuits it is recommended that earthing resistors be bonded together on the hull side of the resistors, and that the means of bonding be separate from that provided by the ship's hull.

#### Protection

1812 In the earthed neutral system generators are to be provided with protection against internal faults. In the insulated neutral system internal fault protection is recommended.

1813 An efficient means of indicating any earth fault in the system is to be fitted.

The indicator may be either:

- (a) a low reading ammeter operating from a current transformer in the neutral, or
- (b) a leakage indicator.

Alternatively, equivalent arrangements ensuring rapid automatic isolation may be fitted.

1814 Any lower voltage system supplied through transformers from the high voltage system is to be earthed or, alternatively, adequate precautions are to be taken to prevent the low voltage system being charged by leakage from the high voltage system.



## Cables, Conductors and Terminations

AMENDED SEE Notice No. 1.

1815 High voltage cables may be installed:—

(a) In the open, e.g. on carrier plating, when they are to be provided with a continuous metallic sheath or armour which is effectively bonded to earth to reduce danger to personnel, or

(b) Contained in earthed metallic ducting or pipe when the cables may be as in (a) or the armour or metal sheath may be omitted. In the latter case care is to be taken to ensure that ducts or pipes are electrically continuous and that short lengths of cable are not left unprotected. Other cables are not to be run in the same ducts or pipes as high voltage cables.

1816 Where practicable, high voltage cables are not to be run through accommodation spaces.

1817 High voltage cables are to be segregated as far as practicable from cables operating at lower voltages.

1818 All high voltage cables are to be readily identifiable by suitable marking.

1819 When single core cables are used precautions are to be taken against circulating currents in the sheath or armour and the cables are to be transposed at intervals of about 16 m.

1820 All high voltage equipment is to be so designed and located that adequate space is provided to ensure efficient cable terminations.

1821 Wherever practicable all conductors are to be effectively covered with suitable insulating material. In terminal boxes if conductors are not insulated, phases are to be separated from earth and from each other by substantial barriers of suitable insulating material.

## Switchgear

1822 All circuit-breakers are to be of the fully withdrawable type.

## Machines

1823 A lower limit of 200 kW is recommended for 3 kV machines and 400 kW for 6 kV machines.

## Section 19

## LIGHTNING CONDUCTORS

## General

1901 Lightning conductors are to be fitted to each mast of all wood, composite, and steel ships having wooden masts or topmasts. They need not be fitted to steel ships having steel masts.

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## Construction

1902 In wood and composite ships fitted with wooden masts, the lightning conductors are to be composed of continuous copper tape and/or rope, having a section not less than 100 mm<sup>2</sup> which are to be riveted with copper rivets or fastened with copper clamps to a suitable copper spike not less than 13 mm in diameter, projecting at least 150 mm above the top of the mast. Where tape is used the lower end of the tape is to terminate at the point at which the shrouds leave the mast, and is to be securely clamped to a copper rope of not less than 13 mm diameter. This copper rope is to be led down the shrouds and is to be securely clamped to a copper plate not less than 0,2 m<sup>2</sup> in area, fixed well below the light waterline and attached to the ship's side in such a manner that it is to be immersed under all conditions of heel.

1903 In wood and composite ships fitted with steel masts, each mast is to be connected to a copper plate in accordance with 1902, the copper rope being securely attached to and in good electrical contact with the mast at or above the point at which the shrouds leave the mast.

1904 In steel ships fitted with wooden masts, the lightning conductors are to be composed of copper tape or rope terminating in a spike, as set forth in 1902. At the lower end this copper tape or rope is to be securely clamped to the nearest metal forming part of the hull of the ship.

1905 Lightning conductors are to be run as straight as possible, and sharp bends in the conductors are to be avoided. All clamps used are to be of brass or copper, preferably of the serrated contact type, and efficiently locked. No connection is to be dependent on a soldered joint.

1906 The resistance of the lightning conductor, measured between the mast head and the position on the earth plate or hull to which the lightning conductor is earthed, is not to exceed 0,02 ohms.

## Section 20

## TRIALS

## General

2001 Before a new installation, or any alteration or addition to an existing installation, is put into service the following trials are to be carried out. These trials are in addition to any acceptance tests which may have been carried out at the manufacturers' works.



**Insulation Resistance**

**2002 INSTRUMENTS**—Insulation resistance is to be measured using a self-contained instrument such as a direct reading ohmmeter of the generator type applying a voltage of at least 500 V.

Where a circuit incorporates capacitors of more than 2 microfarads total capacitance, a constant-voltage type instrument is to be used to ensure accurate test readings.

(a) **POWER AND LIGHTING CIRCUITS**—The insulation resistance between all insulated poles and earth and, where practicable, between poles is to be at least 1 megohm.

The installation may be sub-divided and appliances may be disconnected if initial tests produce results less than this figure.

(b) **INTERNAL COMMUNICATION CIRCUITS**—Circuits operating at 50 V and above are to have an insulation resistance between conductors and between each conductor and earth of at least 1 megohm.

Circuits operating at less than 50 V are to have an insulation resistance of at least 0.33 megohm.

(c) **SWITCHBOARDS, SECTION BOARDS AND DISTRIBUTION BOARDS**—The insulation resistance is to be at least 1 megohm when measured between each busbar and earth and between busbars. This test may be made with all circuit-breakers and switches open and all fuse links for pilot lamps, earth fault-indicating lamps, voltmeters, etc., removed and voltage coils temporarily disconnected, where otherwise damage may result.

(d) **GENERATORS AND MOTORS**—The insulation resistance of generators and motors, in normal working condition and with all parts in place is to be measured and recorded.

The test should be carried out with the machine hot, if possible. The insulation resistance of generator and motor cables, field windings and control gear is to be at least 1 megohm.

**Earth Continuity**

**2003** Tests are to be made to verify that all earth continuity conductors are effective and that the bonding and earthing of metallic conduit and/or sheathing of cables is effective.

**Performance**

**2004** It is to be demonstrated that the Rules have been complied with in respect of:—

Satisfactory commutation and performance of each generator throughout a run at full rated load.

Temperatures of joints, connections, circuit-breakers and fuses.

The operation of engine governors, synchronizing devices, overspeed trips, reverse-current, reverse-power and over-current trips and other safety devices.

Voltage regulation of every generator when full rated load is suddenly thrown off.

For a.c. and d.c. generators, satisfactory parallel operation and kW load sharing of all generators capable of being operated in parallel at all loads up to normal sea or harbour working load. For a.c. generators satisfactory parallel operation and kVA load sharing of all generators capable of being operated in parallel at all loads up to normal sea or harbour working load.

All essential motors and other important equipment are to be operated under service conditions, though not necessarily at full load or simultaneously, for a sufficient length of time to demonstrate that they are satisfactory.

Propulsion equipment is to be tested under working conditions and operated in the presence of the Surveyors and to their satisfaction. The equipment is to have sufficient power for going astern to secure proper control of the ship in all normal circumstances. In passenger ships the ability of the machinery to reverse the direction of thrust of the propeller in sufficient time, under normal manoeuvring conditions, and so bring the ship to rest from maximum ahead service speed is to be demonstrated at the sea trial.

**Voltage Drop**

**2005** Voltage drop is to be measured, where necessary, to verify that this is not excessive. See M 814.

**Section 21****SPARE GEAR**

**2101** The following articles of spare gear, so far as they are applicable, are to be carried. Items used are to be replaced or made good by the Owners as opportunity occurs.

**2102** One set of brushes and one set of bearings for one machine for each size of generator and for each size of motor engaged on essential services, such as those indicated below:—

Air compressors for heavy oil engines.

Scavenge blowers.

Air pumps.

Ballast pumps.



Bilge pumps.  
 Circulating and cooling water pumps.  
 Condenser circulating pumps.  
 Extraction pumps.  
 Feed water pumps.  
 Fire pumps.  
 Fuel valve cooling pumps.  
 Lubricating oil pumps.  
 Oil fuel pumps and oil fuel burning units.  
 Cargo refrigerating motors, including compressors, brine pump, circulating pump, fans, etc.  
 Fans for forced draught to boilers.  
 Steering gear.  
 Windlasses.  
 Ventilating fans for engine room and boiler rooms.  
 Oil separators.

#### Steering Gear

2103 For each size of steering gear motor and motor-generator if no stand-by electrical machine is installed, the following spare gear is required in addition to the spares for motors enumerated above:—

- (a) Direct current machinery:—
  - 1 spare armature of each size fitted complete with shaft and half coupling.
  - 1 spare field coil of each type fitted.
- (b) Alternating current machinery:—
  - 1 spare stator complete of each size fitted.

#### Fans for Refrigerating Equipment

2104 For electrically-driven air circulating fans the following spare gear will be required, in addition to the spares enumerated in 2102 for each size of motor installed, except where a duplicate fan motor in accordance with N 370 is installed:—

- 1 motor complete, or
- Direct current machinery:—
  - 1 armature complete.
  - 1 complete set of field coils.
  - 1 complete set of brush gear.
  - 1 set of bearings.
- Alternating current machinery:—
  - 1 stator complete.
  - 1 set of bearings.

#### Control Gear

2105 For the starting gear of motors, such as those enumerated in 2102:—

- 1 set of contacts which are subject to burning or wear.
- 1 set of springs.
- 10 per cent of each different resistance element, but at least one of each.
- 1 of each type of shunt coil used for contactors, relays or low voltage release.

For six or less starters in which these parts are interchangeable it will be sufficient to provide one set of spares for the starter employing the greatest number of parts.

#### Switchgear and Distribution Boards

2106 For each type of circuit-breaker on each pole:—

- 1 set of contacts which are subject to burning or wear.
- 1 set of parts subject to wear.
- 1 set of springs.
- 1 shunt trip coil and 1 resistance element, of each kind used.
- 15 per cent but not less than six of each type of cartridge or other non-renewable fuses.
- Rewireable fuse-handles; 5 per cent, with a minimum of one, of each size or type used, provided that not more than 12 need be supplied.

#### Navigating and Signal Lights

2107 Navigating and signal lights and their pilot lamps for indicating devices:—

- 1 complete spare set of lamps.

#### Emergency Lighting

2108 Where supplied from storage batteries of a voltage different from the ship's circuit:—

- 1 complete spare set of lamps.

#### Electric Couplings

2109 For each size of electric coupling used for propulsion purposes, the following is required as a minimum:—

- 1 complete set of brush gear.
- 1 field coil of each type fitted.
- 1 set of brushes for one coupling.
- 1 gauge for checking the magnetic air gap.
- Spares for the control gear and switchgear as above.



**Propulsion Equipment**

**2110** Owing to the varied characteristics of equipment an exact list of spares cannot be specified but the following should be provided as a minimum:—

(a) **GENERATORS, MOTORS AND EXCITERS**—One set of bearing bushes, with oil rings, if used, of each size and type for the propulsion generators, motor and exciter.

Two lines of brush holders of each size and type.

One set of carbon brushes for one generator exciter, and one motor.

One shunt field coil of each size and kind used for direct current generators, exciter and motors.

One set of slip rings for one motor if of the alternating current type.

(b) **SWITCH AND CONTROL GEAR**

One set of contacts liable to burning or wear.

One set of springs.

10 per cent of each different resistance element, but at least one of each.

One of each type of shunt wound coil used for contactors, relays, or trip coils.

Two fuse handles of each type and size, or 15 per cent, but not less than six of each type of fuse.

## RECOMMENDATIONS FOR ELECTRICAL EQUIPMENT

The following recommendations are for those features of the electrical installation which are not considered to be the concern of classification and therefore are not included in Chapter M. It should be clearly understood that these recommendations are not mandatory and are intended merely for the use of those Shipowners and Shipbuilders who may seek more guidance on equipment standards than is given in the Rules.



# RECOMMENDATIONS FOR ELECTRICAL EQUIPMENT

## Section 1

### GENERAL

#### Earthing

Rule 108. The following items do not require to be earthed:—

- (i) Lamp caps.
- (ii) Shades, reflectors and guards supported on lighting fittings constructed of or shrouded in insulating material.
- (iii) Metal parts or screws in, or through, insulating material which are thereby separated from current carrying parts in such a way that they cannot become live or come into contact with earthed parts.
- (iv) Portable appliances having double insulation.
- (v) Bearing housings which are insulated in order to prevent circulation of current in the bearings.
- (vi) Clips for fluorescent lamps.
- (vii) Cable clips.
- (viii) Apparatus supplied at extra low voltage.
- (ix) Fixed apparatus or parts of apparatus which, although not shrouded in insulating material is so guarded that it cannot be touched and cannot come in contact with exposed metal.

## Section 2

### SYSTEMS OF SUPPLY

It is recommended that in alternating current systems for socket outlets where special precautions against shock are necessary, e.g. portable boiler cleaning tools where the operator works in a confined space and his skin will be damp, the following maximum voltages should be used:—

- (i) Supplied direct 55 V
- (ii) Where a safety isolating transformer is used supplying only one socket outlet 250 V

## Section 4

### ROTATING MACHINERY

With the exception of machines for purely domestic purposes such as motors of vacuum cleaners, portable tools and galley equipment it is recommended that all machines comply with the requirements of M 4. Machines for domestic purposes should comply with a National or International standard.

#### Short-circuit

Sudden short-circuit tests, when required by the purchaser, should be a matter for agreement between purchaser and manufacturer. If carried out they should be made at an initial terminal voltage not greater than the rated voltage of the machine and at rated frequency.

#### Field Regulation of Direct Current Generators

Rule 417. This requirement will be met if at the conclusion of the full load temperature test, with full load current and normal full load voltage at the terminals when running at full load engine speed, the voltage across the shunt field regulator, with an ambient air temperature of 15°C, is not less than 14 per cent of the terminal voltage of the machine. This makes allowance for the difference in field resistance between average test conditions and the most severe service conditions.

#### Transient Voltage Response of Alternating Current Service Generators

Rule 423. To meet this requirement it is recommended that one of the following alternatives be applied as determined by the characteristics of the installation, but such a test should not be required if evidence can be produced that a test has been carried out on a similar machine.

(a) *When the starting kVA of the motors is 35 per cent or less of the capacity of the generating plant and where a rapid voltage recovery is not required.*

With the generator driven at its rated speed at no load and giving its rated voltage under the control of the AVR, the maximum voltage change should not exceed 15 per cent when a current equal to 35 per cent full load current at any power factor between zero and 0.4 lagging is suddenly



drawn. The voltage should be restored to within 3 per cent of rated voltage in not more than 1,5 seconds.

(b) *When the starting kVA of the largest motor or group of motors liable to be started simultaneously exceeds 35 per cent but is less than 60 per cent of the capacity of the generating plant.*

With the generator driven at its rated speed at no load and giving its rated voltage under the control of the AVR the maximum voltage change should not exceed 15 per cent when a current equal to 60 per cent full load current at any power factor between zero and 0,4 lagging is suddenly drawn. The voltage should be restored to within 3 per cent of the rated voltage in not more than one second.

(c) *When the starting kVA of the largest motor or group of motors liable to be started simultaneously exceeds 60 per cent of the capacity of the generating plant, or when the recovery time of one second is not satisfactory for the operation of special devices supplied by the same generating plant.*

A specification of the performance of the generating plant should be agreed between purchaser and manufacturer.

#### Wattless Load Sharing

Rule 425. This requirement may be otherwise stated:—

“When alternating current generators are operated in parallel, the wattless loads of the individual generating sets should not differ from their proportionate share of the total wattless load by more than 10 per cent of the rated wattless output of the largest machine.”

Rule 425 gives a more convenient method of measuring wattless load sharing but other methods can be used, e.g. measurement of the power factor.

#### Frequency

When running alternating current motors from a shore supply of lower frequency, care should be taken to lower the terminal voltage at the motors in proportion to frequency in order not to overload the motors.

### Section 5

#### DISTRIBUTION

It is recommended that in machinery spaces, large galleys and such spaces as corridors, stairways leading to boat decks and public rooms, lighting should be supplied

from at least two final sub-circuits one of which could be the emergency circuit so that failure of one circuit does not reduce the lighting to an inadequate level.

#### Steering Gear

Where electric power is used for the operation of steering gear it is recommended that failure of supply be indicated by audible and visual alarms in the engine room and/or pilot house.

In any steering gear where electric control only is used it is recommended that the control be duplicated.

### Section 6

#### SWITCHBOARDS, SWITCHGEAR AND PROTECTIVE EQUIPMENT

All main and emergency switchboards should be provided with hand rails in front of the panel. Where the switchboard is of the open type the rail should be non-conducting. The platform in front of and behind switchboards should have a non-slip surface.

Where necessary, insulated hand rails should be fitted behind switchboards, and passageways behind switchboards should be provided with access doors at each end, these to be capable of being opened from the passageway. The doors should bear a prominent and permanent notice giving the maximum voltage.

For voltages between poles or to earth exceeding 250 V direct current or 55 V alternating current, switchboards should be of the dead front type. Where the voltage exceeds 55 V during operation an insulating mat should be provided.

Where an earth indicating system using either two or three lamps is used, the lamps should be of metal filament type each not exceeding 30W. They should be of the same colour and placed not more than 150 mm apart.

For preference tripping systems, the following over-current settings are recommended (expressed as a percentage of the rated current of the generator or circuit to be protected):—

Main generator circuit-breaker	150 per cent
Preference tripping relays	110 per cent

Time delays should be established in accordance with the nature of the load the following values being given as an example:—

First tripping circuit-breaker	5 seconds
Second tripping circuit-breaker	10 seconds
Third tripping circuit-breaker	15 seconds
Main generator circuit-breaker	20 seconds

For overloads less than 10 per cent, protection may



## RECOMMENDATIONS FOR ELECTRICAL EQUIPMENT

consist of an alarm signal operated by a time delayed relay set to approximately 110 per cent rated current of the generator.

The two-wire circuits of rating exceeding 100 A should be controlled as a minimum in one insulated pole or phase by a switch. Three-wire alternating current circuits rated at more than 60 A should be controlled by a triple-pole linked switch.

The minimum operating current of every circuit-breaker should be not greater than twice the rating of the smallest conductor which it is installed to protect except for motor circuits where short-circuit protection only is required (in these cases three times the cable rating).

The overcurrent setting of a circuit-breaker will depend on individual arrangements and in motor circuits must be matched to the load temperature characteristics of the motor, the following figures being given merely as an example:—

	Overcurrent
Continuously rated circuits	25 per cent
Intermittently rated circuits	50 per cent
Steering gear and emergency circuits	200 per cent

Circuit-breakers, contactors and switches should be so installed that, so far as practicable, their moving parts and associated relays are not live when the circuit-breaker or contactor is in the OFF position.

Circuit-breakers and contactors should be provided with a means of isolation.

In large installations, where fault levels are high, circuit-breakers should be of the power operated type.

In earthed systems of large capacity, protection against internal faults in the generators should be considered.

All generators arranged for parallel operation with one another or with the shore power feeder should be provided with undervoltage release which prevents the closing of the appropriate circuit-breaker until the generator terminal voltage reaches at least 70 per cent of the rated voltage.

The installation of automatic circuit opening devices, other than for short-circuit protection, is not recommended in exciter circuits.

In alternating current systems consideration should be given to the fitting of an automatic trip to main generator circuit-breakers which will open the breaker on loss of excitation.

The fitting of an ammeter in exciter circuits is recommended.

### Selection of Fuses

(i) Fuses for steady load circuits, such as heating circuits, should be of current rating at least equal to that of the apparatus. If other overcurrent protection is provided

or if discrimination requires it, a fuse of greater current rating may be necessary.

(ii) Fuses for fluctuating load circuits, such as motor circuits, transformer circuits, lighting circuits and capacitor circuits, should have a time/current characteristic which allows the transient overcurrent to be carried without operation of the fuse. It will sometimes be necessary to select fuses of a current rating greater than that of the circuit.

For motor circuits it will be necessary to obtain particulars of the magnitude and duration of the starting current and to select fuses by referring to the time/current characteristics.

## Section 8

### CABLES

In large installations where short-circuit currents may be high it is recommended that cables are armoured, and in three-phase installations, so far as is practicable, three-core cables carrying the three-phase currents should be employed.

Where these precautions are necessary particular care should be taken with the cable supports especially at the ends of cables.

In 110 V installations where lighting cables may be fully loaded, are bunched together and are installed between wooden panelling or similar locations, it is recommended that the minimum size of conductor be not less than 2.5 mm<sup>2</sup>.

## Section 10

### LIGHTING

In bathrooms, galleys, laundries and similar places the parts of a lampholder likely to be touched should be constructed of or shrouded in insulating material and fitted with a protective shield, or totally enclosed fittings should be used.

Lighting switches for bathrooms and similar locations should be outside such spaces unless they are of construction suitable for humid conditions.

Lamps which are used near combustible material should be installed in totally enclosed fittings.

Where tubular fluorescent lighting is used, lighting by one or more filament lamps should be provided, especially in compartments containing running machinery.



Lamps which are used in spaces liable to contain explosive or flammable materials should be installed in flameproof fittings.

Filament lamps are recommended for emergency lighting.

Live parts of fluorescent lighting installations should be screened with earthed metal or insulating material.

#### Connections to Lighting Fittings

Due to the reduced physical sizes of lamps in many countries, e.g. 100 W lamps can now be installed in many fittings that previously were designed for 60 W lamps, care must be taken with cable connections so that the maximum conductor temperature is not exceeded. Tests carried out in the past have shown a temperature rise at some lamp-holder terminals of 80°C and a distance about 16 mm from the lampholder terminals exhibited a temperature rise of 60°C.

Where cables operate at temperatures in excess of the permitted maximum, deterioration of the insulation occurs with premature failure in service.

Comments on the behaviour of the various classes of insulation are given below:—

##### (a) RUBBER

Maximum conductor temperature 60°C. At higher temperatures it ages with increasing severity, reducing its life.

##### (b) POLYVINYL CHLORIDE

Maximum conductor temperature 60°C. At higher temperatures it may flow away from the conductor when under pressure, e.g. clips.

##### (c) POLYCHLOROPRENE

This is usually associated with rubber when maximum conductor temperature is 60°C. At higher temperatures it absorbs moisture after cooling leading to electrical breakdown.

##### (d) BUTYL

Maximum conductor temperature 80°C. At 130°C it ages rapidly and may turn into a powder which can fall away from the conductor if subject to vibration or shock.

##### (e) SILICONE RUBBER

Maximum conductor temperature 150°C and intermittently up to 200°C.

Fittings should be designed so that the maximum permitted temperature for the cable is not exceeded. Alternatively, high temperature tails (e.g. silicone rubber) should be incorporated in the fitting and led to a terminal block.

## Section 11

### ACCESSORIES

Where differing distribution systems are used any socket outlets and plugs should be of such design that incorrect connection cannot be made.

In general, socket outlets should not be fitted in bathrooms, lavatories and similar wet places.

In systems at 110 V direct current and above or 55 V alternating current and above socket outlets and plugs should be provided with an earthing contact. This contact should make contact before the live pins when the plug is inserted.

#### Heating and Cooking Equipment

Electric heating and cooking equipment should be so constructed that parts which must be handled cannot exceed 55°C.

Heating elements should be readily replaceable.

Connections between elements, switches and supply cables should be carried out with terminals.

Connections between elements and between elements and terminals to which insulated cables may be connected, unless self-supporting and rigidly secured in position should be continuously insulated with incombustible material.

Heating elements should be suitably guarded. Live parts of cooking appliances should be protected so that cooking utensils cannot come into contact with them.

Space heaters in cabins, lockers, etc., should be of the convector type. Space heaters should not be installed in spaces where flammable gases might accumulate.

#### Batteries

Batteries should be located where they are not exposed to excessive heat or extreme cold. Batteries for emergency service, including emergency diesel engine starting should be located above the bulkhead deck. The best operating conditions for batteries are obtained when the working temperature is between 15°C and 27°C. Where practicable the temperature of the electrolyte should not be permitted to exceed 50°C since higher temperatures tend to reduce the life of the battery. Low temperatures may temporarily reduce the capacity of the battery.

Mechanical ventilation of battery rooms should be capable of changing the air in the battery room four or five times per hour.

#### Spare Gear

The provision of an insulation tester is recommended.



# Chapter N

## REFRIGERATED CARGO INSTALLATIONS

### Extracts from Chapter B for reference

**B 901** On application from Owners, refrigerated cargo installations which comply with Chapter N of the Rules and are favourably reported on by the Surveyors will be assigned an appropriate class in accordance with N 1. Certificates will be issued and the class notation, together with the particulars of the installation, will be entered in the Supplement.

**B 902** The class assigned will be retained provided the installation is found to be in a good and efficient condition at the Periodical, Loading Port, and other Surveys set forth in N 8.

**B 903** The paragraphs in B 14 regarding Withdrawal of Class and in B 15 regarding Reclassification, apply also to Refrigerated Cargo Installations.

### Section 1

#### GENERAL

##### Class Notation

**101** The class notation assigned will be Lloyd's RMC followed by the minimum temperature(s) approved by the Committee for the installation with the maximum sea temperature stated, e.g. "to maintain temp.  $-12^{\circ}\text{C}$  in the lower chambers and  $0^{\circ}\text{C}$  in the upper chambers with sea temperature  $30^{\circ}\text{C}$  maximum."

NOTE. The temperature at which the cargo is to be carried is not the responsibility of the Society.

**102** Installations constructed under the Society's special survey in accordance with N 2 to N 6 will be eligible for the distinguishing mark  $\nabla$  before the class notation, thus  $\nabla$ Lloyd's RMC. In other cases the mark  $\nabla$  will not be assigned.

**103** In the case of installations designed to reduce the temperature of non-precooled cargoes, a mark  $\ddagger$  will be shown under the class notation in the Appendix to the Register Book and will be included on the certificate as an indication that an installation has been considered by the Society for this duty. A special statement showing the cargo cooling capabilities of such installations, in respect of stated weights and descriptions of cargoes under stated conditions, will be issued on application by the Owners to the Society's Head Office.

##### Special Cases

**104** The Committee will be prepared to give consideration to cases of ships engaged on voyages of short duration, to installations of small capacity, or to other special circumstances. In such cases the class may include a service limitation or other restriction.

### Refrigerants

**105** These Rules are applicable to the following primary refrigerants:—

Carbon Dioxide

Ammonia

Dichlorodifluoromethane

Monochlorodifluoromethane

Proposals to use other refrigerants will be specially considered on application, but methyl chloride will not be accepted.

### NEW INSTALLATIONS

### Section 2

#### SPECIAL SURVEY DURING CONSTRUCTION

**201** New installations intended for classification are to be constructed under the Society's Special Survey in accordance with the requirements of N 3 and N 4; tests are to be carried out as specified in N 5, and spare gear is to be supplied as listed in N 6.

#### Information and Plans to be Submitted

**202** The following information and plans are to be forwarded, in triplicate, for consideration before construction is commenced:—

- (a) Refrigerating plant—standard data sheet in duplicate. (Copies of this data sheet may be obtained from the Society's local office.)
- (b) Refrigerating plant—detailed specification in triplicate.
- (c) Insulation—detailed specification in triplicate.
- (d) General arrangement of insulated chambers in elevation and plan. The plans are to be to a scale



adequate for the measurement of the external surfaces and the deck and bulkhead edges. Dimensions and spacing of frames, beams and stiffeners and details of other steel work protruding into the insulation and within the chambers are to be shown. Oil fuel and liquid cargo tanks adjacent to or below the chambers are to be indicated, and whether heating is provided for such tanks. Ventilating and air conditioning trunks and ducts passing through chambers are to be shown. The plans should include a diagram showing the position of the chambers in relation to other parts of the ship if this is not otherwise apparent.

- (e) Detailed plans showing the thickness and methods of attachment of the insulation and linings on all surfaces including girders, hatch coamings and pillars; details of insulated doors, and hatch, access, bilge and manhole plugs and their frames. Method of attachment of brine or direct expansion grids and meat rails are also to be shown.
- (f) Arrangement of air ducts (including method of cooling spaces within hatch coamings), air coolers, fans and their motors.
- (g) Air cooler defrosting arrangements, other than hot brine circulating systems.
- (h) Arrangement of brine grids including those in way of hatches; and method of construction.
- (i) Arrangement of chamber thermometers.
- (j) General arrangement of refrigerating machinery.
- (k) Brine circuit diagram with particulars of piping.
- (l) Primary refrigerant gas and liquid circuit diagrams and full particulars of all pressure piping.
- (m) Sectional arrangement of refrigerant compressors.

Detailed dimensioned plans of:—

- (n) Compressor crankshafts.
- (o) Compressor crankcases where exposed to the refrigerant pressure.
- (p) Condensers.
- (q) Evaporators (brine coolers).
- (r) Air coolers.
- (s) Oil separators.
- (t) Liquid receivers.
- (u) All other pressure vessels.
- (v) Similar plans are required for refrigerating plant of other designs.
- (w) Where the refrigerating machines are driven by oil engines particulars and plans are to be submitted in accordance with the requirements of G 104.

- (x) Where the refrigerating machines or air cooler fans are driven by steam engines particulars and plans are to be submitted in accordance with G 104.
- (y) Where air cooler or necessary air stirring fans are electrically driven plans of the motors are to be submitted in accordance with M 429.
- (z) Where it is proposed to apply centralized, bridge or automatic controls, a description of the scheme and particulars of the spares to be carried are to be submitted.

#### Refrigeration Required in Excess of N 306

203 Refrigeration required in excess of that specified in N 306, which may be necessary for rapid cooling of chambers, or cooling cargoes loaded at temperatures above the carrying temperature, is to be in accordance with a specification approved by the Owners.

#### Rate of Air Circulation

204 Where refrigeration is effected by forced air circulation over coolers the proposed fan output in each chamber will be considered in relation to the heat to be removed, the nature of the cargo and the service(s) intended.

Where chambers are intended for the additional duties mentioned in 203 the rate of air circulation is to be in accordance with the Owners' requirements.

#### Subsequent Modifications or Additions

205 Any subsequent modifications or additions to particulars and/or arrangements shown on the approved plans or in the specifications are also to be submitted for approval.

#### Novel Arrangement and Designs

206 Where the proposed construction of the refrigerating plant or refrigerated chambers is novel in design or involves the use of unusual material, special tests may be required, and a suitable class notation may be assigned when the Committee consider this necessary.

#### Survey Requirements

207 From the commencement of the construction and installation of the refrigerating plant and of the insulation and fitting out of the cargo chambers, to the testing of the completed installation, the Surveyors are to examine the materials and workmanship and are to indicate at the earliest opportunity and require the rectification of any items not in accordance with the Rules or the approved specifications and plans, or any material, workmanship or arrangement found to be defective or unsatisfactory.



**Section 3****REFRIGERATING PLANT****Definition of a Unit**

**301** A refrigerating unit comprises a prime mover, one or more refrigerating machines (refrigerant gas compressors), one gas condenser—and in the case of a secondary refrigerant, one brine cooler (gas evaporator)—and the fittings necessary to permit independent operation of the unit.

**302** If the prime mover of a refrigerating machine is a steam engine with two or more cylinders and each cylinder drives a corresponding compressor, or there is more than one motor similarly arranged, and if each compressor is connected to its own condenser and brine cooler (where fitted), the arrangement is to be regarded as two or more units as the case may be, provided the units can be used separately or in combination.

NOTE. Condensers or evaporators of the coil-in-casing type need not necessarily be in separate casings.

**303** Two or more refrigerating machines (or compressors) driven by a single prime mover, or having only one condenser or one brine cooler (where fitted), are to be regarded as one unit.

**304** Where a refrigerating plant is provided for sub-cooling the liquid refrigerant, or cooling the condensers of other refrigerating machines, and is not arranged for cooling the cargo spaces independently, it will not be regarded as a unit.

**305** Where a refrigerating plant is dependent on the main refrigerating units for cooling the condenser or the refrigerant liquid, it will not be regarded as a unit.

**Refrigeration to be Provided**

**306** The refrigeration provided is to be capable of efficiently maintaining the minimum temperature(s) under the conditions applicable to the maximum sea temperature for which approval by the Committee is desired and which is to be specified in the class notation (see N 101), when working 24 hours a day with any one of the refrigerating units out of action. It is recommended that a reasonable margin in plant output over maximum load be allowed for possible overall inefficiencies under service conditions.

**307** Where part of the necessary refrigeration is obtained by the sub-cooling of the liquid refrigerant by other refrigerating plant, one plant supplying such sub-cooling

may be considered sufficient provided the refrigerating units including the standby unit are capable of the full duty specified in 306 in the event of the sub-cooling plant being out of action.

**308** In any case where all the refrigerating units are not connected for use on all the refrigerated cargo chambers the plant serving each chamber is to comply with the requirements of 306.

**309** The foregoing requirements are based on the assumption that installations will have relatively few refrigerating units each arranged to serve all chambers. In the case of installations having a large number of small units arranged to serve individual chambers, or groups of chambers, the question of reserve plant will be the subject of special consideration.

**Number of Refrigerating Units**

**310** Not less than two complete refrigerating units are to be fitted. Where two units only are fitted the working parts are to be interchangeable.

**Standby Pumps**

**311** A standby gas condenser cooling water pump is to be installed ready for use in addition to the pumps required for the full duty specified in 306. This standby pump may be one of the pumps used for other purposes provided it is of adequate capacity and its use on the gas condenser does not interfere with other essential services.

**312** Where brine is used for refrigerating the cargo chambers a standby brine circulating pump is to be installed ready for use in addition to the pumps required for the full duty specified in 306.

**Sea Connections**

**313** Condenser cooling water is to be taken from not less than two sea connections, one of which may be that provided for other purposes, such as the water ballast inlet. It is recommended that one of the sea connections be provided on the port and the other on the starboard side.

**Location of Machinery**

**314** Where ammonia refrigerant is used the refrigerating machinery is to be in an efficiently ventilated compartment isolated from the propelling machinery spaces and shaft tunnels, and living quarters.

Machinery using non-toxic and non-flammable refrigerants will not be subject to restriction on location in general, but proposals to install relatively large plants in propelling machinery spaces will require special consideration.



**Prime Movers**

**315** Where refrigerating plant is electrically driven the motors and their control gear are to comply with the requirements of M 4 and M 7.

**316** Where the refrigerating machinery is steam driven the steam engines are to comply with the requirements of Chapters G and H and the exhaust steam is to be led to the main and auxiliary condensers.

**317** Where the refrigerating machinery is driven by oil engines the requirements of Chapters G and H are to be carried out.

**Motive Power**

**318** In the case of 315 the electric power is to be taken from at least two generators (*see also* M 403) and in the case of 316 steam is to be taken from at least two boilers, each capable of the maximum duty without interference with other essential services.

**Plant on Ships not Classed with the Society**

**319** In the case of refrigerating installations being constructed under the Society's Special Survey on ships not intended to be classed with this Society, the generator engines and electrical equipment, which supply power to the refrigerating installations, should be constructed in accordance with the requirements of the Classification Society concerned, but such plant is to be examined generally and under working conditions.

**Steel Castings**

**320** Important steel castings are to comply with the requirements of Q 5.

**Steel Forgings**

**321** Crankshafts and other important steel forgings are to comply with the requirements of Q 6.

**Dimensions of Crankshafts**

**322** Crankshafts of single acting reciprocating refrigerant compressors, of mild steel having a tensile breaking strength of 430-490 N/mm<sup>2</sup> (44-50 kgf/mm<sup>2</sup>) are to have dimensions not less than those calculated from the following formulæ.

Where crankshafts are proposed to be made of steel of greater strength or of other material, the particulars including the material specification are to be submitted for special consideration.

**323** The formulæ are applicable to compressors operating on the normal cycle, with crankshafts having one, two, three or four cranks at equal angles and one cylinder acting on each, and with two or more main bearings.

**324** The formulæ are also applicable to compressors, other than CO<sub>2</sub> having the crank and cylinder arrangements as shown in Table N 3.1, but in these cases the calculated shaft diameter is to be increased by 5%, 18% and 25% when the angle between cylinders is 90°, 60° and 45° respectively.

**TABLE N 3.1**

NUMBER OF CRANKPINS	NUMBER OF CYLINDERS PER CRANK	ANGLE BETWEEN CYLINDERS
1 or 2	2	45°, 60° or 90°
3	2	45° or 60°
4	2	45° or 60°
1	3	45°, 60° or 90°
2	3	45° or 60°
3	3	45°
1	4	45° or 60°
2	4	45°

**325** The formulæ are not applicable to crankshafts having more than one crank on the same top centre, or to compressors where the cylinders are arranged for supercharging by gas of higher pressure at an intermediate stage of the stroke.

**Diameter of Crankshafts****326****TABLE N 3.2**

REFRIGERANT	DIAMETER OF CRANKSHAFT (ALL DIMENSIONS IN mm)
Carbon Dioxide (CO <sub>2</sub> )	$\sqrt[3]{D^2 \left( 15 \frac{ab}{a+b} + 1,25S \right)}$ for gas discharge pressures up to 10,3 N/mm <sup>2</sup> (105 kgf/cm <sup>2</sup> )
Ammonia (NH <sub>3</sub> ) Monochlorodifluoromethane (CHClF <sub>2</sub> )	$\sqrt[3]{D^2 \left( 2,5 \frac{ab}{a+b} + 0,15S \right)}$ for gas discharge pressures up to 1,72 N/mm <sup>2</sup> (17,5 kgf/cm <sup>2</sup> )
Dichlorodifluoromethane (CCl <sub>2</sub> F <sub>2</sub> )	$\sqrt[3]{D^2 \left( 1,5 \frac{ab}{a+b} + 0,1S \right)}$ for gas discharge pressures up to 1,03 N/mm <sup>2</sup> (10,5 kgf/cm <sup>2</sup> )



where  $D$  = cylinder diameter,

$S$  = length of stroke,

$a$  = distance from the inner edge of one bearing to the centreline of the crankpin nearest the centre of the span,

$b$  = distance from the centreline of the same crankpin to the inner edge of the other bearing,

$a + b$  = distance (or span) between the inner edges of adjacent main bearings.

**327** Where it is proposed to make solid forged crankshafts of steel having a specified minimum tensile strength greater than 430 N/mm<sup>2</sup> (44 kgf/mm<sup>2</sup>), but not exceeding 780 N/mm<sup>2</sup> (80 kgf/mm<sup>2</sup>), the diameter of the crankshaft is not to be less than given by the following formula:—

$$\text{Diameter of crankshaft} = d \times \sqrt[3]{\frac{430}{0,72T + 124}} \text{ mm}$$

$$\left( d \times \sqrt[3]{\frac{44}{0,72T + 12,6}} \text{ mm} \right)$$

where  $d$  = diameter, in mm, of crankshaft made of steel having a specified minimum tensile strength of 430 N/mm<sup>2</sup> (44 kgf/mm<sup>2</sup>) as required by 326,

$T$  = proposed specified minimum tensile strength in N/mm<sup>2</sup> (kgf/mm<sup>2</sup>).

#### Crankwebs

**328** Crankwebs are to be of the following proportions or of equivalent strength:—

Breadth of web =  $1,33 \times$  calculated shaft diameter

Thickness of web

adjacent to a bearing =  $0,56 \times$  calculated shaft diameter

Thickness of

intermediate webs =  $0,75 \times$  calculated shaft diameter

### CAST IRON CRANKSHAFTS

#### General

**329** Where it is proposed to make crankshafts of cast iron, the material specification and the dimensions of the shaft are to be submitted for special consideration.

#### Material

**330** The material specification should state the type of cast iron, the heat treatment, and mechanical properties, including the specified minimum tensile strength appropriate to the section of the crankshaft casting.

**331** Any suitable type of high duty cast iron may be used, provided the minimum specified tensile strength is between 310 and 750 N/mm<sup>2</sup> (32 and 76 kgf/mm<sup>2</sup>). Crankshafts are to be cast at a foundry approved for the production of cast iron crankshafts. (See Q 8).

#### Crankshafts

**332** The diameter of the crankshaft is not to be less than that given by the following formula:—

$$\text{Diameter of crankshaft} = d \times \sqrt[3]{\frac{215}{0,3T + 77,5 - \frac{d}{4,9}}} \text{ mm}$$

$$\left( d \times \sqrt[3]{\frac{22}{0,3T + 7,9 - \frac{d}{48}}} \text{ mm} \right)$$

where  $d$  = diameter, in mm, required by 326 for a steel crankshaft having a tensile strength of 430 N/mm<sup>2</sup> (44 kgf/mm<sup>2</sup>),

$T$  = specified minimum tensile strength of cast iron in N/mm<sup>2</sup> (kgf/mm<sup>2</sup>) which is not to be less than 310 N/mm<sup>2</sup> (32 kgf/mm<sup>2</sup>).

**333** Special consideration will be given to crankshafts which have been designed and developed for optimum fatigue strength with cranks of the most favourable shape, and some allowance made for the superior strength thereby obtained. Particulars of any relevant tests or experience should be submitted.

#### Crankwebs

**334** The proportions of the crankwebs are to be as stated in 328.

#### Fillets and Oil Holes

**335** Fillets at the junctions of crankwebs with crankpins or journals are to be machined to a radius of not less than 5 per cent of the diameter of the crankshaft and are to have a smooth finish.

Oil holes at the surfaces of crankpins and journals are to be rounded to an even contour with a smooth finish.

#### Crankshafts for Compressors of Other Designs

**336** The particulars of crankshafts for double acting or compound compressors, and for other refrigerants or arrangements, are to be submitted for special consideration.



**Maximum Working Pressures**

337 The components of primary refrigerant pressure systems including piping, stop valves and headers are to be designed for a maximum working pressure of not less than :—

10,3 N/mm<sup>2</sup> (105 kgf/cm<sup>2</sup>) for carbon dioxide (CO<sub>2</sub>),

1,72 N/mm<sup>2</sup> (17,5 kgf/cm<sup>2</sup>) for ammonia (NH<sub>3</sub>) and monochlorodifluoromethane (CH Cl F<sub>2</sub>),

1,03 N/mm<sup>2</sup> (10,5 kgf/cm<sup>2</sup>) for dichlorodifluoromethane (C Cl<sub>2</sub> F<sub>2</sub>).

In the case of crankcases which are exposed to the refrigerant pressure the design pressure is to be not less than :—

1,37 N/mm<sup>2</sup> (14 kgf/cm<sup>2</sup>) for ammonia and monochlorodifluoromethane,

0,69 N/mm<sup>2</sup> (7 kgf/cm<sup>2</sup>) for dichlorodifluoromethane.

Crankcases designed for a lower pressure are to be provided with a pressure relief valve arranged to lift at the design pressure and the discharge led to a safe place.

If desired a lower design pressure may be considered for other parts of the low pressure side of the system.

The design pressure for other refrigerants which may be proposed will be considered on application, but as a general guide this will be the saturated vapour pressure at 46°C.

**Refrigerant Pressure Vessels**

338 Welded cylindrical pressure vessels which are of steel construction and exposed to the pressure of the refrigerant are to be constructed in accordance with the requirements of J 1 to J 6 so far as applicable and the pressure tests are to comply with 346.

339 Where ammonia is the refrigerant, pressure vessels are to be constructed to not less than Class 2/2 fusion welded requirements.

340 Where pressure vessel shells are made of steel tube the tubes are to comply with the requirements of Q 7 and E 5 so far as applicable, except that the formula for determining the minimum thickness of straight shells as defined in E 512 shall be modified to:—

$$T = \frac{PD}{2f + P} + 0,75 \text{ mm}$$

The pressure tests are to comply with 346.

341 Where ammonia is the refrigerant, pressure vessel shells are not to be manufactured from lap welded pipes.

342 Where pressure vessels are of forged seamless construction, they are to comply with the requirements of J 201 and Q 6 so far as applicable, and the pressure tests are to comply with 346.

343 Where it is proposed to construct pressure vessels of materials other than steel, or not of cylindrical form, full particulars will be required for special consideration.

**Pressure Pipes**

344 Steel piping for primary refrigerants is to comply with the requirements of E 5, except that a corrosion allowance of 1 mm be added to the formula in E 512.

Butt welding of pipe lengths in lieu of flanged joints is to be carried out as required in E 5 under the supervision and to the satisfaction of the Surveyors.

Where the pipes are galvanized, a short part at the ends about 100 mm long, is either to be left ungalvanized or the galvanizing is to be removed before welding.

345 Where it is proposed to use pipes of materials other than steel, full particulars are to be submitted for consideration.

**Pressure Tests**

346 The pressure tests as in Table N 3.3 are to be witnessed by the Society's Surveyors at the makers' works. The hydraulic test may be carried out with any suitable liquid. When it is inconvenient to test the large NH<sub>3</sub> (ammonia) condensers and evaporators by submersion in water the shells may be charged with air and gas, and tested by some suitable means. In the case of C Cl<sub>2</sub> F<sub>2</sub> (dichlorodifluoromethane) and CH Cl F<sub>2</sub> (monochlorodifluoromethane) a suitable gas may be used in lieu of air.

Where difficulty may arise in testing components separately, proposals to test more than one component as a unit should be submitted for consideration in cases where the required test pressures are different for the separate components.

**Tests after Erection on Board Ship**

347 Carbon dioxide systems are to be examined for gas leaks when the system is charged. Ammonia and monochlorodifluoromethane systems are to be tested to a gas or air pressure of not less than 1,37 N/mm<sup>2</sup> (14 kgf/cm<sup>2</sup>).

Dichlorodifluoromethane systems are to be tested by a suitable gas to a pressure of not less than 0,69 N/mm<sup>2</sup> (7 kgf/cm<sup>2</sup>).

Brine systems are to be tested to a hydraulic pressure of double the working pressure but not less than 0,34 N/mm<sup>2</sup> (3,5 kgf/cm<sup>2</sup>). Where the hydraulic test is not reasonably



TABLE N 3.3

REFRIGERANT	COMPONENT	MINIMUM TEST PRESSURE	
		Hydraulic N/mm <sup>2</sup> (kgf/cm <sup>2</sup> )	Air* N/mm <sup>2</sup> (kgf/cm <sup>2</sup> )
CO <sub>2</sub>	Components subject to gas pressure:— Compressor cylinder blocks, stop valves, condenser and evaporator coils, and other components.	20,6 (210,0)	10,3 (105,0)
	Fusion welded and seamless pressure vessels in accordance with 338, 340 and 342. Pressure piping in accordance with 344.	as per J 445 as per E 523	10,3 (105,0) 10,3 (105,0)
NH <sub>3</sub> and CH Cl F <sub>2</sub>	Components subject to gas pressure:— Compressor cylinders and stop valves.	4,12 (42,0)	2,06 (21,0)
	Compressor crankcases	2,06 (21,0)	1,03 (10,5)
	Condenser, evaporator and air cooler coils.	10,3 (105,0)	3,43 (35,0)
	Condenser and evaporator coils or grids welded to headers, and other components.	3,43 (35,0)	1,72 (17,5)
	Fusion welded and seamless pressure vessels in accordance with 338, 340 and 342.	as per J 445	1,72 (17,5)
	Pressure piping in accordance with 344.	as per E 523	1,72 (17,5)
C Cl <sub>2</sub> F <sub>2</sub>	Components subject to gas pressure:— Crankcases.	1,37 (14,0)	1,03 (10,5)
	Small machines with cylinders up to 115 mm dia. where the cylinders and crankcases are in one casting.	2,06 (21,0)	1,37 (14,0)
	Fusion welded and seamless pressure vessels in accordance with 338, 340 and 342.	as per J 445	1,03 (10,5)
	Pressure piping in accordance with 344.	as per E 523	1,03 (10,5)
	All other components in the system.	2,40 (24,5)	1,37 (14,0)
	Cooling liquid side of refrigerant condensers.	2WP but not less than 0,1 N/mm <sup>2</sup> (1,0 kgf/cm <sup>2</sup> )	
Brine	Air cooler coil assembly.	0,69 (7,0)	
	Cast iron casings of refrigerant evaporators.	2WP but not less than 0,1 N/mm <sup>2</sup> (1,0 kgf/cm <sup>2</sup> )	
	Steel casings of refrigerant evaporators on suction side of pump.	2 × head pressure but not less than 0,2 N/mm <sup>2</sup> (2,0 kgf/cm <sup>2</sup> )	
	Steel casings of refrigerant evaporators on discharge side of pump.	2WP but not less than 0,34 N/mm <sup>2</sup> (3,5 kgf/cm <sup>2</sup> )	
	Open casings of brine evaporators.	Filled to top	

\*Component submerged in water at 32°C.

possible, sections of brine leads (service pipes) which have to be insulated before the circuits are complete may be tested by an air pressure of 0,59 N/mm<sup>2</sup> (6 kgf/cm<sup>2</sup>).

#### Oil Separators

348 Suitable oil separators with drains are to be provided to the refrigerant lines. If wire gauze is used in the separator it is to be sufficiently robust and supported to prevent disintegration.

#### Filters (strainers)

349 Suitable filters are to be provided in the refrigerant gas lines to compressors and in the liquid lines to the regulators. Wire gauze in filters is to be sufficiently robust and supported to prevent disintegration. A filter may be combined with the oil separator required by 348.

#### Refrigerant Driers

350 Driers are to be fitted in monochlorodifluoromethane and dichlorodifluoromethane refrigerant systems, and the arrangement is to be such that the drier can be by-passed, isolated and opened up without interrupting plant operation.

#### Brine Systems

351 Where brine is the cooling medium it is recommended that the 'closed' system with a brine balance tank be adopted in every case.

#### Safety Devices

352 A pressure relief valve and/or safety disc is to be fitted between each compressor and its gas delivery stop valve, the discharge being led to the suction side of the compressor. Where the motive power for the compressor does not exceed 10 kW the pressure relief valve and/or safety disc may be omitted.

353 All pressure vessels of refrigerant systems which could become filled with liquid refrigerant and isolated are to be provided with safety discs and relief valves in series, or other approved arrangements, the discharge being led to a safe place above deck.

354 Suitable spring-loaded safety valves are to be provided to the cooling liquid side of condensers and the brine side of evaporators where the pressure from any pump connected could cause a pressure in excess of the maximum working pressure.

#### Access to Plant

355 The arrangements are to be such that all components of the refrigerating machinery can be readily

opened up for inspection or overhaul. Space is to be provided for the withdrawal and renewal of the tubes in 'shell-and-tube' type evaporators (brine coolers) and condensers.

356 Where the coils of 'coil-in-casing' type evaporators (brine coolers) and condensers are unwieldy and cannot readily be withdrawn, two suitably arranged inspection holes are to be provided in the top plate, in the sides at about half-height and in the sides at the bottom. The holes are to be as large as practicable and not less than 230×150 mm.

#### Manual Control

357 Where plants are operated by thermostatic refrigerant control, efficient manual controls are also to be provided, and the arrangement is to be such that thermostatic controls can be by-passed and isolated.

As an alternative, duplicate thermostatically operated refrigerant control valves may be fitted, each valve to be capable of the required duty and operable with the other out of action.

#### Refrigerating Plant of Other Design

358 Particulars of refrigerating plant of designs other than those mentioned in these Rules (e.g. steam jet vacuum refrigeration plants) are to be submitted for special consideration.

#### Cooling Appliances in Refrigerated Chambers

359 Chambers may be refrigerated by pipe grids on the ceiling and sides or by the circulation of air over coolers.

360 Refrigeration by pipe grids in the chamber is to be effected by the circulation of brine, except in the case of installations or chambers of very small capacity when the direct expansion of the refrigerant will be considered. The pipe grids in each chamber are to be arranged in not less than two sections. Each section is to be fitted with valves or cocks so that it can be shut off.

361 Either brine or the direct expansion of the refrigerant may be employed in the coils of air coolers. The coils are to be arranged in not less than two sections each of which is to be capable of being readily isolated when necessary.

362 The brine or direct expansion leads to, and returns from, the cooling appliances in each chamber are preferably to be in duplicate.



**363** In order to minimize the dehydration of the cargo and the frosting of the cooling elements, it is recommended that the cooling appliances in each chamber should be designed to maintain the required minimum temperature under the maximum difference of not more than 4,5°C between the cooling medium and the chamber.

**364** Where the joints of brine pipes are made by screwed couplings, the pipes, coupling and back nut threads are to be a good fit and the thickness of the pipes at the bottom of the screw thread is to be not less than 2,5 mm.

**365** Where the joints of air cooler and grid piping are butt welded they are to comply with 344.

**366** Steel brine and refrigerant piping, grids, joint sleeves and coils within the refrigerated cargo chambers, or where embedded in insulation, or individually insulated, are to be galvanized externally. Where such pipes are connected by screwed couplings or by butt welds, the screw threads clear of the couplings or the butt welds and the adjoining ungalvanized portions of the piping, are to be suitably coated and taped after pressure testing to prevent corrosion. The locations of the joints are to be marked on the outside of the insulation.

**367** Brine tanks and piping should not be galvanized on the brine side. In cases where any parts of the brine system are so treated, the brine cooling and return tanks, if closed, are to be provided with a ventilating pipe or pipes led to the atmosphere in a location where no damage will arise from the gas discharged, and the ventilating pipes are to be fitted with wire gauze diaphragms which can readily be removed. Where the brine tanks are not closed, the compartments in which they are situated are to be efficiently ventilated.

**368** Means are to be provided for defrosting air coolers.

**369** Air coolers are to be provided with trays of suitable depth arranged to collect all water condensate. The trays are to be provided with drains at the bottom so that the whole of the condensate can be drained away when the chambers are in service.

**370** Access arrangements to air cooler fans and fan motors are to be such that both fans and motors may be readily removed for repair or renewal when the chambers are loaded with refrigerated cargo. Access for servicing only is required in cases where duplicate fans and motors, each capable of the full duty, are installed ready for use; this also applies to centrifugal type fans but not to their motors.

**371** The air circulation system is to be arranged for positive air delivery to, or suction from, all parts of the chamber, including any space within hatch coamings.

**372** Where it is intended to carry fruit cargoes which may be adversely affected by low temperatures, into sea areas where the temperature may be below the carrying temperature, facilities for heating the chambers are to be provided.

#### Air Refreshing Arrangements

**373** Where chambers are intended for the carriage of gas-generating cargoes, air refreshing appliances are to be provided.

The position of the air inlets is to be carefully selected to minimize the possibility of vitiated air from any source entering the chambers. Each chamber is to be provided with individual inlets and discharges, having airtight closing appliances.

### Section 4

#### CARGO CHAMBERS

##### Construction

**401** Each individual chamber is to be of steel construction throughout and hose-tested for tightness, or tested more thoroughly by gas and air under slight pressure when required by the Owners.

**402** At the request of Owners, special consideration will be given to the construction of divisional bulkheads of materials other than steel, between refrigerated cargo chambers where the chambers concerned are intended for cargoes which will not taint or otherwise adversely affect the cargo in any other chamber.

NOTE. Gases given off by fruit of one category may adversely affect fruit of another category by promoting rapid ripening.

**403** Hatch plugs and their supports, chamber, air cooler and other access doors, tonnage openings, bilge limbers and plugs are to be made as airtight as possible.

**404** Ventilators, ducts or pipes passing through refrigerated chambers to other compartments are to be made airtight and efficiently insulated. Ventilators to refrigerated spaces, if fitted, are to be provided with airtight closing appliances.

##### Airtightness of the Bulkheads and Decks

**405** Where refrigeration pipes pass through bulkheads or decks of refrigerated cargo chambers they are not to be in direct contact with the steelwork, the holes through



which they pass are to be true and of suitable finish for effectively sealing by the method intended. It is recommended that holes be trepanned and not burnt out. The airtightness of the bulkheads and decks is to be maintained (*see also* 408 and 413).

#### Airtightness of Chambers

406 The foregoing paragraphs, 401 to 405, are mainly concerned with infiltration of odours, gases, water vapour and air, which may taint or adversely affect the refrigerated cargo or the insulation, or cause undesirable frosting of cooling equipment. With this object in view it is also recommended that insulation lining, bilge limbers and plugs, hatch plugs, chamber and access doors be constructed of water vapour-resisting material, or covered with such material, and sealed, where exposed to bilges or external conditions.

#### Insulation

407 Steelwork is to be thoroughly cleaned and coated in accordance with D 2 and is to be examined for airtightness of fittings before insulation is applied.

Insulating material approved by the Committee is to be used throughout, and the thickness of insulation over all surfaces and the manner in which it is supported are to be in accordance with the approved specification and plans.

The insulation is to be efficiently packed and, where it is of slab form, the joints are to be butted closely together and staggered, unavoidable crevices being filled with insulating material. Bitumen should not be used for filling crevices.

408 Pipes carrying the refrigerating medium are not to be in contact with the steel structure and are to be effectively insulated outside the chambers they serve, except within insulated brine cooler and control rooms (*see also* 405 and 413).

#### Cross-references

409 For insulation of oil storage tank tops and bulkheads, *see* E 345 and E 346.

For pipes in refrigerated spaces, *see* E 416 to E 418.

For drainage of refrigerated spaces and cooler trays, *see* E 211 to E 216.

For use of fork lift trucks in refrigerated spaces, *see* D 421.

#### Protection of Insulation

410 The insulation in way of the hatchways and about 0,6 m beyond on the tank top and the tunnel top is

to be protected with hardwood sheathing about 50 mm thick, or to have similar protection.

#### Access Plugs and Panels

411 Insulated plugs are to be provided in the insulation where required for easy access to the bilges, bilge suction roses, cooler and space drains and tank manhole doors. Removable panels are to be provided for access to tank air and sounding pipes and drains.

It is recommended that, where no air space is provided below the insulation on the tank tops and the floor covering above the insulation is reinforced asphalt, a number of small insulated inspection plugs be fitted for leakage detection.

Where "loose fill" insulation is fitted and lined with metal it is recommended that airtight inspection plates be provided at the top of vertical surfaces to facilitate inspection and making good any settlement.

#### Fire-resisting Insulation

412 The insulation in way of coal bunkers and of any surfaces exposed to excessive heat is to be of approved fire-resisting material. Where wood grounds are used for supporting insulation, asbestos strips are to be fitted between the wood grounds and the steelwork to which they are attached.

Where pipes carrying the refrigerating medium pass through bunkers the pipes may be packed with granulated cork but there is to be a thick outer covering of fire-resisting material and the whole is to be protected by steel plates which are to be sealed for airtightness.

#### Watertight Bulkhead Fittings

413 Where cooling pipes pass through watertight deck plating and bulkheads, the pipes are not to be in contact with the steelwork, and the fittings and packings of the glands are to be both fire-resisting and watertight (*see also* 405 and 408).

#### Airtightness of Insulation Lining and Air Ducts

414 Air ducts and insulation linings are to be so constructed and fitted that moving air is prevented from entering the insulation. Special care is necessary where cooling pipes, air refreshing ducts, fan supports, etc., protrude through the lining.

#### Cargo Battens

415 Cargo battens are to be secured to the insulation linings at the sides and bulkheads of chambers and at other



vertical surfaces such as large rectangular section pillars, to provide a space for the circulation of air between the surfaces and refrigerated cargo. Cargo battens need not be fitted in way of air ducting, screens and cooler casings. The battens are to be arranged to suit the direction of air flow, and their outer edges are to be chamfered.

Battens should generally be about 50×50 mm spaced approximately 400 mm apart, but smaller battens at closer spacing will be considered in conjunction with the air circulation system and the types of cargo to be carried.

**416** Cargo battens of not less than 75×75 mm are to be secured over the tunnel top insulation.

#### Stiffening of Insulation Linings and Air Ducts

**417** Insulation linings and air screens on the sides of chambers are to be suitably stiffened to prevent crushing by cargo, in particular where ship sides are curved inwards and according to the nature of the cargo, whether general or refrigerated, which the Owners intend to carry in the chambers. Air duct sides or insulation linings which may have to support heavy loads are to be constructed to Owners' requirements.

#### Galvanizing of Fixtures

**418** All steel bolts, nuts, hangers, brackets and fixtures which support or secure cooling appliances, insulation, meat rails, etc., are to be galvanized.

#### Thermometers

**419** Thermometers are to be of approved type, number and position in each chamber.

**420** Thermometer tubes with their flanges and covers are to be insulated from the deck plating, and on weather decks they are to be so arranged that water will not run down the tubes when taking the temperatures.

**421** The inside diameter of thermometer tubes is to be not less than 50 mm and the tubes are not to be in contact with cold decks.

**422** Where thermometer tubes pass through compartments other than those which they serve, they are to be efficiently insulated.

**423** When electric remote reading temperature measurement is used in lieu of direct reading thermometers for the cargo chambers or air circulation system, the instruments and equipment are to be of approved type and are to comply with 424 to 430 and N 501.

**424** Performance is to be satisfactory and accuracy is to be maintained during voltage and frequency fluctuations given in M 105, at all ambient temperatures up to and including those given in M 106, and in addition, construction is to comply with M 107 where applicable.

**425** The readings of temperature shall be accurate to within  $\pm 0,15\text{degC}$  of the true temperature in the range  $-3^{\circ}\text{C}$  to  $+3^{\circ}\text{C}$ , and to within  $\pm 0,25\text{degC}$  in other parts of the temperature range. These requirements will apply at all ambient temperatures to which the instrument and connecting parts may normally be exposed in use up to  $50^{\circ}\text{C}$ , and in the usual conditions of inclination and vibration associated with marine service.

For scale instruments, the scale deflection should not be less than 5 mm/degC with division markings enabling the indication to be estimated within one-tenth of a degree. The range of temperature will normally be between  $-29^{\circ}\text{C}$  and  $+21^{\circ}\text{C}$ .

**426** At least two instruments are to be provided for each installation, with the sensing elements so connected that in the event of a failure of any one instrument, at least one sensing element will be operative for each chamber, either in the chamber or in its air circulation system.

Where a data logger is installed and all the sensing elements are connected to this single instrument, at least one sensing element in each chamber or in its circulating air system is to be connected to a separate instrument of approved type. The display of data loggers is to be in digital form or other equally effective visual indication, registering to one-tenth of a degree.

**427** Where galvanometers are fitted, two are to be provided for each indicating instrument and a checking resistance fitted.

**428** Where instruments have individual power supply units, a spare power unit, e.g. transformers and rectifier or battery is to be provided for each instrument.

**429** All temperature sensing elements are to be permanently connected, plug and socket connections not normally being acceptable between the elements and the instruments.

Wiring between the sensing elements and the instruments is to be in accordance with Chapter M. All junction boxes are to be provided with cable glands and all connections are to be of a permanent nature, such as soldered or compression type connections.

**430** In order to obtain type approval, plans and specifications of the temperature indicating instrument and



equipment are to be forwarded for examination. These are to include details of all components, of the sensing elements, leads and sheathing, and of selector switches and junction boxes.

The instrument and equipment are to be constructed in accordance with the approved plans and specifications.

In order to determine the suitability of the instrument and equipment, the Surveyors will examine a typical installation at the makers and witness appropriate tests to determine that the degree of accuracy complies with 425. The ability of the instrument to withstand vibration, shock and other typical marine service conditions will be given particular attention.

## Section 5

### TESTS AFTER COMPLETION

#### Thermometers

501 All thermometers and equipment for measuring chamber and air suction and delivery temperatures are to be installed on board in accordance with the approved plans and the relevant paragraphs of N 4, and the whole installation completed to the satisfaction of the Surveyors.

Each thermometer is to be checked for accuracy by the contractors and a statement giving the readings to the nearest tenth of a degree at the freezing point of water handed to the Surveyors. The Surveyors may use their discretion as to whether check tests are necessary.

In the case of electric remote reading instruments a statement of calibration for each instrument indicating the method employed is to be supplied.

#### Air Cooler Fan Outputs and Air Circulating Arrangements

502 Air cooler fans are to be tested by the contractors after the air circulating system has been completed and a statement of the results for each chamber handed to the Surveyors. The statement is to show the static pressure, the cubic metres of air circulated per minute, the fan speed and the power consumption. The air circulation arrangements in the chambers are to be checked for distribution.

#### Refrigeration Test

503 All plant is to be tested under working conditions and the capabilities of the installation checked by a heat balance test.

Before the commencement of the test the Surveyors are to satisfy themselves that the electrical instruments, gauges and thermometers are accurate.

The chambers are to be cooled down to the temperatures required in the class notation, but not necessarily at the balance period. Unless the decks are insulated so that the steel is exposed to the ambient temperature (*see* D 428) the chamber temperatures are not to be reduced by more than 1degC below the notation temperatures except by special arrangement and with the agreement of the Owners and the Builders.

When the chamber balance test temperatures have been reached they are to be maintained constant for a stabilizing period during which heat is removed from the insulation, etc., in the chambers, and thereafter the temperatures maintained constant for a balance period of 6 hours, or longer if found necessary.

To maintain steady balance temperatures compressor speed or power input to the fan motors may be varied, or if necessary compressors may be run on stop-start cycles. Cylinder unloading should be avoided where possible and devices for varying cylinder duty should not be used. All such adjustments and stop-start cycles are to be carefully logged.

504 Observations are to be recorded from the beginning of cooling down to the end of the test. In the early stages logging may be at intervals of about 4 hours, but external temperatures should be logged hourly for the final 18 hours of the test, and all other relevant temperatures and pressures, speed and power consumption of compressor and fan motors, power consumption of brine and cooling water pumps logged hourly for the final 12 hours of the test.

505 Where an installation is to be completed and tested during a period when extremely low external temperatures are probable and a reasonable difference between the external and internal temperatures will not be possible without reducing the chamber temperatures below the level referred to in 503, the case is to be submitted for special consideration.

506 In cases where it is reasonable to believe that the refrigerating plant is inefficient, an output test on the plant may also be required.

#### Air Cooler Defrosting Arrangements

507 The air cooler defrosting arrangements are to be tested.



**Section 6****SPARE GEAR**

**601** The following spare gear will be required in all cases :—

- 1 fan impeller of the propeller type of each size used.
- 1 set of the wearing parts of the crankshaft seals for each compressor where the crankcase is subject to the refrigerant pressure.
- 1 set of crankshaft coupling bolts of each size used.
- 1 set of motor coupling bolts and washers, of each size used.
- 1 compressor piston with piston or connecting rod complete, of each size used.
- 1 complete assembly of each size of compressor suction and delivery valve.
- 1 complete set of packing for CO<sub>2</sub> compressor piston rod glands of each size used.
- 1 set of the working parts, together with packing and piston leathers, for the lubricating oil pump for CO<sub>2</sub> compressor rod glands.
- 1 gas regulator valve of each size used.
- 1 float regulator assembly of each size used.
- 1 set of suction and delivery valves for cooling water, air and brine pumps, of each size used.
- 1 set of driving belts of each size used.
- Sundry lengths and bends of piping together with flanges, couplings and screwing appliances.
- Sundry cocks, valves, flanges and fittings.
- Assorted bolts, nuts, studs, packing and joint rings.
- 5 per cent of the total number of electrical or tube thermometers, but not less than two of each.
- Not less than two standard thermometers of the necessary temperature range.
- 1 spare battery for each electric thermometer indicator fitted.
- 1 hydrometer, where brine is the cooling medium.
- 1 halide lamp leak detector, where dichlorodifluoromethane or monochlorodifluoromethane is the refrigerant.
- 2 safety valve springs of each size used.
- 6 safety discs of each size used.

In cases where approval is given to alternative arrangements under N 104, additional spare gear may be required according to the circumstances of the case.

**602** Where steam driven air circulating fans are fitted, the following spare gear will be required :—

For each size used :—

- 1 crankshaft.
- 1 steam piston and rod complete.
- 1 steam cylinder cover.
- 1 set of connecting rod top and bottom end bearing bushes, and bolts complete.

**603** Where the refrigerating machines are direct driven by steam engines or by oil engines, the spare gear is to be in accordance with Chapter K.

**604** Where any component of the refrigerating plant is electrically driven the spare gear is to be in accordance with M 2102, and in the case of fan motors, M 2104, except where a duplicate fan motor (*see* N 370) is installed ready for use.

**605** It is assumed that the Owners will arrange for the necessary reserve supply of the refrigerant, calcium chloride and oils for the voyage intended.

**Section 7****INSTALLATIONS NOT CONSTRUCTED UNDER SURVEY**

**701** When classification is desired for an installation not constructed under the supervision of the Society's Surveyors, application is to be made to the Committee in writing.

**702** Full particulars and plans are to be forwarded for consideration, together with the particulars of the materials of the crankshafts, pressure vessels and pressure piping. The requirements of N 202 are to be used for guidance in regard to the information required.

**703** A special examination is to be made at least to the extent required for subsequent Special Surveys. (*See* N 849 to N 857.)

**704** The thickness and material of the insulation, the particulars of the frames, beams, stiffeners and other steel work within the insulation, the air coolers and/or chamber grid piping, the compressors, evaporators and condensers are to be verified, and the particulars of the other components of the refrigerating plant are to be verified so far as practicable.

**705** The installation is to conform with the requirements of N 2, N 3, N 4 and N 6, so far as applicable.



706 A test is to be carried out in accordance with N 503 to N 505, and air circulation arrangements in the chambers are to be checked for air distribution.

## Section 8

### PERIODICAL AND OTHER SURVEYS

#### Incidence of Surveys

801 For the retention of the class assigned, installations are to be subjected to the periodical surveys specified in the following paragraphs.

#### Running Survey

802 A Running Survey as detailed in 815 to 829 is to be held at intervals of 12 months, and as detailed in 830 to 837 at the intervals stated therein.

Where desired by the Owners, Running Surveys may be held at shorter intervals of time.

In special circumstances, the Committee will be prepared to consider postponement of a Running Survey for a period not exceeding 2 months, provided application is made by the Owners prior to the due date of the survey and provided a Loading Port Survey is carried out as near to this date as possible.

#### Special Survey

803 A Special Survey as detailed in 839 to 857 is to be held at 4-yearly intervals, the first 4 years after the date of the survey for classification and thereafter 4 years from the date of the previous Special Survey.

A Special Survey will normally become due at the same time as a Running Survey, but when they do not coincide, the date assigned to the Special Survey will be that of the Running Survey.

Where it is inconvenient for Owners to fulfil the Special Survey requirements at the due date, the Committee will be prepared to consider its postponement, either wholly or in part, for a period not exceeding 12 months from the due date, provided prior application is made by the Owners, and provided the Running Surveys continue to be held at the specified intervals. Any special circumstances which may arise will require to be dealt with as necessary.

#### Continuous Special Survey of Insulation

804 At the request of Owners, the Committee may agree to the Special Survey requirements of 844 to 846 being carried out on a Continuous Survey basis on ships in which the Continuous Hull Survey system has been accepted.

In these cases the insulation in the compartments concerned and the insulation of the refrigerant piping should be exposed or removed as required by the Surveyors, in rotation, with an interval of 5 years between consecutive examinations of each part.

If the examination during Continuous Surveys reveals any defects, further parts are to be opened up and examined as considered necessary by the Surveyor.

#### Survey of Repairs

805 Where any essential repairs and/or renewals are effected to an installation, they are to be carried out under the supervision and to the satisfaction of the Society's Surveyors. Repairs and renewals effected at ports where there is no Surveyor to this Society are to be surveyed by one of the Society's Surveyors at the earliest opportunity.

#### Alterations and Additions

806 Plans and particulars of any proposed alterations or additions to the refrigerated cargo chambers or the refrigerating plant are to be submitted for approval before the work is put in hand, and the work is to be carried out under the supervision and to the satisfaction of the Society's Surveyors.

#### Record of Surveys

807 The date following the class notation "Lloyd's RMC" on the certificate indicates the date when the installation was first classed.

The notation "RS" (with date) indicates the date of the last Running Survey.

The notation "SRMC" (with date) indicates the date of the last Special Survey.

When the requirements of the Continuous Special Survey and all other requirements of the Special RMC Survey have been completed the notation assigned will be "SRMC (CSI)" (with date).

The notations when assigned will be recorded in the appropriate section of the *Register Book* and in the *Supplements*.

#### Notice of Surveys

808 It is the responsibility of Owners to ensure that all surveys necessary for the maintenance of class are carried out at the proper time under the supervision of the Society's Surveyors.

It is, however, the normal practice of the Society to give timely notice to Owners when Periodical Surveys of Refrigerated Cargo Installations become due, but the non-receipt of such notice does not absolve Owners from this responsibility.



**Loading Port Survey**

809 When a Loading Port Certificate is required by the Owners or their representatives, a survey as detailed in 810 to 814 is to be carried out at the loading port. The certificate is not in respect of the cargo to be loaded or the manner in which it is to be stowed.

In the case of ships engaged on voyages of less than 2 months duration, a Loading Port Certificate will be considered as valid for 2 months, provided the cargoes carried are of such a nature as not to damage the insulation or appliances in the insulated chambers, nor to affect by taint or mould the refrigerated cargoes loaded during that period.

810 The chambers are to be examined in an empty state to ascertain that they are clean and free from odour which may adversely affect the cargo to be loaded, that the brine or other refrigerant pipe grids, cooler coils and connections are free from leakage, that the fixed cargo battens on the vertical surfaces are in good order, that cargo gratings or dunnage battens are provided for the floors or decks and that no damage has been sustained to the insulation or its lining prior to the loading of the refrigerated cargo. Any indications of defective insulation not considered to warrant immediate attention should be noted and specially reported.

811 The Surveyor is to satisfy himself that all scuppers and bilge suctions draining insulated spaces are in good working order, and that the liquid seals are primed.

812 The refrigerating installation is to be examined under working conditions, and the temperatures in the cargo chambers are to be noted.

813 If the ship loads at more than one port, one survey only at the first loading port will be required, provided it includes the examination of all the chambers which are to be used for refrigerated cargo during the voyage and general cargo is not subsequently carried in any of the chambers prior to loading the refrigerated cargo.

814 If there is no Surveyor to the Society available at the loading port(s), or if none is obtainable from a port within a reasonable distance, the Committee will accept the report of a survey held at the loading port by a Surveyor appointed by Lloyd's Agent; or in any case where there is no Lloyd's Agent, the report of a survey held by a reliable Surveyor, if available; if no such Surveyor is available, a report signed by two competent engineers of the ship will be accepted.

**RUNNING SURVEYS****General**

815 Whenever practicable, the machinery in use is to be examined under working conditions on the ship's arrival at the port of discharge before the refrigerated cargo is unloaded.

Log books or other records should be examined and any breakdowns or indications of deficiency in the installation are to be noted and reported.

**Cargo Chambers**

816 The cargo chambers are to be examined throughout.

817 Insulation linings and fastenings on the sides, bulkheads and deckheads are to be examined so far as practicable for condition and airtightness. The removal of parts of the linings, or drilling, is not required unless insulation deficiency is known or suspected, but any indication of dampness or leakage into the insulation from tanks, decks, scuppers or other source is to be investigated.

818 The coverings on deck, tank top and tunnel top insulation are to be examined for condition and shrinkage. Where there is evidence of deterioration or dampness the insulation is to be tested by drilling and parts of the covering removed if found necessary.

819 Air ducting and cooler casings, and the fastenings and supports for ducts, grids and meat rails are to be examined so far as practicable for damage or deterioration.

820 Hatch plugs and supports, patent hatch covers and seals, chamber and access doors and frames, bilge and manhole plugs, air refreshing pipes and their closing appliances are to be examined for condition and airtightness.

821 The bilges are to be cleaned and suction pipes suction roses, sounding pipes and scupper non-return valves examined. The Surveyor should satisfy himself that all scuppers draining the chambers and cooler trays are in good working order.

**Air Coolers and Grids**

822 Air cooler coils, cooling grids and valves are to be examined. The Surveyor should satisfy himself that sections of the coils or grids are not choked and that the valves are in good working order.

823 Brine refrigerant cooler coils and grids are to be examined while under a pressure of 1,5 times the working pressure or 0,3 N/mm<sup>2</sup> (3 kgf/cm<sup>2</sup>) whichever is the greater.



**824** Primary refrigerant cooler coils and grids are to be examined while under the refrigerant pressure prevailing in the system at the time of the survey, with the plant at rest and the regulating valves opened just sufficient to obtain an approximate balance of pressure throughout the system, and to avoid accumulation of liquid in the coils or grids.

#### Primary Refrigerant Pressure Vessels and Connections

**825** The shells of shell-and-tube and double-pipe type condensers and evaporators, separators, receivers, driers, filters and other pressure vessels, and the coil terminals of coil-in-casing type condensers and evaporators, are to be examined so far as practicable.

In the case of pressure vessels covered by insulation any evidence of dampness or deterioration of the insulation which could lead to external corrosion of the vessels or their connections is to be investigated.

#### Piping and Headers

**826** Primary refrigerant gas and liquid pipes, brine piping, headers, condenser cooling water piping and valves are to be examined so far as practicable.

Where parts of the piping or headers are covered by insulation an examination of the insulation is to be made as in 825.

#### Thermometers

**827** The thermometers for measuring the chamber, air suction, and air delivery temperatures are to be examined and where repairs or renewals are found necessary the thermometers concerned are afterwards to be checked for accuracy.

Each thermometer is to be tested for accuracy at intervals not exceeding the period between Special Surveys, but not necessarily all at one time. The Surveyor may at his discretion accept the results of thermometer tests carried out by a competent staff or contractor.

NOTE. In a number of ships, thermometers of a type not approved by the Society have been fitted in addition to those required by N 419: the former need not be examined or tested.

#### Fans and Fan Motors

**828** A general examination is to be made of air cooler fans, their motors, control gear and cables and the insulation resistance measured. The insulation resistance is not to be less than 100 000 ohms, and for the purpose of this test each item may be taken separately. The Surveyor may at his discretion accept the results of tests carried out by a competent staff or contractor.

#### Generating Plant

**829** The generating plant supplying electric power to the refrigerating machinery is to be examined generally with a view to ascertaining that the plant is being efficiently maintained.

In the case of ships not classed with the Society, the Surveyor is to ascertain that periodical examinations of the generating plant continue to be held by the Classification Society concerned.

#### Compressors

**830** Each reciprocating compressor, including those provided for sub-cooling the primary refrigerant, is to be opened up at intervals of 2 years and examined in accordance with (a) and (b) alternately.

(a) Cylinder bores, valves and seats, glands, relief devices, suction filters and lubricating arrangements are to be examined. Crankcase doors are to be removed for a general examination, and crankshaft bearing surfaces exposed if required by the Surveyor.

(b) In addition to the examination described in (a), pistons, piston rods, connecting rods, and the crankshaft are to be examined. Crankcase glands and the lower halves of main bearings need not be exposed if the Surveyor is satisfied as to alignment and wear.

**831** Alternatively, each compressor may be opened up after each period of 5000 running hours and examined in accordance with 830 (a) and 830 (b) alternately, but the interval between examinations in accordance with 830 (b) is not to exceed 4 years unless in special circumstances an extension of this period is agreed by the Committee.

Where this system is adopted it will be the Owners' responsibility to maintain a record of the running hours of each compressor, and to ensure that neither periods of 5000 running hours between examinations, nor 4 years between examinations in accordance with 830 (b), are exceeded.

It will be the Surveyor's responsibility to examine the records at Running Surveys and to report the number of running hours logged by each compressor since it was last examined.

Where other than reciprocating compressors are fitted, or where there is a programme of replacement instead of surveys on board, other survey arrangements may be necessary. Each case will be given individual consideration.

#### Condensers

**832** The water end covers of shell-and-tube and double-pipe type condensers are to be removed for examination of the tubes, tubeplates and covers, in rotation, approximately half the number of condensers to be examined annually so that all are examined in a period of 2 years.



Where there are several separate installations in a ship, the number of condensers to be examined annually will be specially considered for each case.

#### Condenser Cooling Water Pumps

833 The working parts of condenser cooling water pumps, including the standby pump which may be used on other services, are to be examined in regular rotation so that all are examined in a period of 2 years.

If there are two or more standby sources of cooling water supply the examination may be extended over a period of 4 years and is to include at least two standby pumps, approximately half the number of pumps to be examined in each 2-year period.

#### Brine and Primary Refrigerant Circulating Pumps

834 The working parts of brine and primary refrigerant pumps are to be examined in rotation so that all are examined in a period of 2 years.

#### Prime Movers

835 Where a refrigerating compressor, water, brine or primary refrigerant pump is electrically driven, a general examination is to be made of the motor, control gear and cables and the insulation resistance measured as in 828, at the same time as the compressor or pump is being examined.

Where a compressor or pump is driven by a steam or internal combustion engine, all the working parts of the engine are to be opened up and examined in a similar manner to that specified for compressors in 830, at the same time as the compressor or pump is being examined.

#### Steam Jet Vacuum Refrigerating Plant

836 Steam jet plant forming the primary refrigerant system is to be examined in rotation at Running Surveys so that all parts, including flash chambers, water spray arrangements, thermo-compressor steam chambers, nozzles, condensers, pumps and ejectors are examined in a period of 2 years.

#### Spare Gear

837 The refrigerating plant spare gear is to be checked.

#### Survey Records

838 A Survey book or other permanent record is to be kept on board the ship to show the date of examination of the various parts. This is to be available to the Surveyor at all times and is to be signed by the Surveyor on the occasion of each survey.

NOTE. The Surveyor may ask for additional items to be opened up for examination if considered necessary at any survey.

#### FIRST SPECIAL SURVEY

839 In addition to the requirements for Running Survey as detailed in 815 to 837, the following are to be complied with.

840 Where the refrigerating machinery is driven by internal combustion engines, and independent air compressors and air receivers exclusive to the refrigerating plant are installed, the working parts of the compressors and their intercoolers, filters, oil separators and safety devices are to be examined. The air receivers with their mountings, valves and safety devices are to be cleaned internally and examined internally and externally. If internal examination of the air receivers is not practicable, they are to be tested hydraulically to twice the working pressure.

841 The Surveyor is to satisfy himself that all pressure relief valves and/or safety discs throughout the refrigerating plant are in good order. No attempt, however, should be made to test primary refrigerant pressure relief valves on board ship.

842 In the case of steam jet vacuum refrigerating plants installed for sub-cooling the primary refrigerant liquid, the flash chambers and water spray arrangements, the thermo-compressor steam chambers and nozzles, the condensers, the cooled water circulating, condenser cooling and condensate extraction pumps, and the air pumps or ejectors are to be examined and, if considered necessary, the condensers are to be tested.

843 Sufficient insulation is to be stripped from insulated pressure vessels to allow the condition of the vessels and their connections to be ascertained. Care is to be taken that on replacement of the insulation the vapour sealing of the outer covering is made good.

844 Sufficient insulation is to be stripped from pipes carrying the refrigerating medium at various points of the system, both outside and inside the chambers, to permit the condition of the pipes to be ascertained. Care is to be taken that on replacement of the insulation the vapour sealing of the outer covering is made good.

845 Sufficient air trunking and insulation lining is to be stripped from the chamber overhead and vertical surfaces to allow the condition of the insulation, insulation linings, grounds, supports, hangers and fixtures which support the insulation, grids, meat rails, etc., to be ascertained. Care is to be taken that on replacement the ducts and linings are sealed against air blowing into the insulation.



846 Sufficient tank top insulation is to be stripped to allow the condition of the grounds and inner insulation lining to be ascertained.

847 Sea connections to condenser cooling water pumps are to be opened up and examined.

848 Steam pipes to steam engines driving refrigerating machinery, and to steam jet vacuum refrigerating plants are to be examined as required by C 11 if the temperature of the steam is over 454°C.

In the case of installations on unclassified ships, the Surveyors are to ascertain whether the steam pipes have been similarly dealt with by the Classification Society concerned, and if not, arrangements are to be made for the examination and tests in accordance with C 11.

#### SUBSEQUENT SPECIAL SURVEYS

849 In addition to the requirements for First Special Survey as detailed in 839 to 848, the following are to be complied with.

850 The coils of gas condensers of the coil-in-casing type are to be examined and tested to a pressure of 1,72 N/mm<sup>2</sup> (17,5 kgf/cm<sup>2</sup>) for dichlorodifluoromethane systems, 6,86 N/mm<sup>2</sup> (70 kgf/cm<sup>2</sup>) for ammonia and monochlorodifluoromethane systems, and 13,73 N/mm<sup>2</sup> (140 kgf/cm<sup>2</sup>) for carbon dioxide systems. Where it is impracticable to remove the coils they may be examined and tested in place.

851 The coils of evaporators (brine coolers) of the coil-in-casing type are to be examined and tested to a pressure of 1,37 N/mm<sup>2</sup> (14 kgf/cm<sup>2</sup>) for dichlorodifluoromethane systems, 3,43 N/mm<sup>2</sup> (35 kgf/cm<sup>2</sup>) for ammonia and monochlorodifluoromethane systems, and 10,30 N/mm<sup>2</sup> (105 kgf/cm<sup>2</sup>) for carbon dioxide systems. Where it is impracticable to remove the coils they may be examined and tested in place.

852 Gas condensers of the shell-and-tube type, and gas evaporators (brine coolers) of the shell-and-tube type in which the primary refrigerant is in the shell, are to have the water or brine end covers removed and the shell pneumatically tested with the refrigerant or air, or a mixture of inert gas and refrigerant, to a pressure of 0,69 N/mm<sup>2</sup> (7 kgf/cm<sup>2</sup>) for dichlorodifluoromethane systems and 1,37 N/mm<sup>2</sup> (14 kgf/cm<sup>2</sup>) for ammonia and monochlorodifluoromethane systems.

853 Gas evaporators (brine coolers) of the shell-and-tube type in which the brine is in the shell are to have the primary refrigerant end covers removed and the shell hydraulically tested to twice the design pressure but to not less than 0,3 N/mm<sup>2</sup> (3 kgf/cm<sup>2</sup>).

After refitting the end covers the primary refrigerant side is to be pneumatically tested as stated in 852, and an examination made as far as practicable for gas leakage in the shell with the brine connections removed.

854 Primary refrigerant liquid sub-cooling coils in flash chambers of steam jet vacuum refrigerating plants are to be examined and tested to the same pressure as that required for condensers in 850.

855 Where brine or water is used for sub-cooling the primary refrigerant liquid in heat exchangers of the shell-and-tube type, the heat exchangers are to be examined and tested in the same manner as that required for condensers in 852.

Double-pipe type heat exchangers are to be examined so far as practicable with the gas piping under the same pressures as that required for condensers in 852 and the water or brine from the outlets is to be tested for gas leakage.

Other types of heat exchangers using brine or water are to be examined and tested at the discretion of the Surveyor according to the design of such equipment.

856 Primary refrigerant chamber grids or air cooler coils are to be tested in place to a pressure of 0,69 N/mm<sup>2</sup> (7 kgf/cm<sup>2</sup>) for dichlorodifluoromethane, 1,03 N/mm<sup>2</sup> (10,5 kgf/cm<sup>2</sup>) for ammonia and monochlorodifluoromethane systems, and 6,86 N/mm<sup>2</sup> (70 kgf/cm<sup>2</sup>) for carbon dioxide systems.

857 Steam pipes to steam engines driving refrigerating machinery, and to steam jet vacuum refrigerating plants are to be examined as required by C 11.

In the case of installations on unclassified ships, the Surveyors are to ascertain whether the steam pipes have been similarly dealt with by the Classification Society concerned, and if not, arrangements are to be made for the examination and tests in accordance with C 11.

#### Section 9

##### REFRIGERATED FREIGHT CONTAINERS WITH SELF-CONTAINED REFRIGERATING UNITS

##### General

901 Refrigerated freight containers with self-contained refrigerating plant carried on ships and under supervision and maintenance by the ship's staff as refrigerating installations, are eligible for classification. They are to comply with N 1 to N 8 in so far as they are applicable, together with the following paragraphs.

902 The Owners' name and an identification number are to be clearly marked on each container.



**903** Where a container has not been constructed and tested as in 904, it is to be indicated on the container that it is not to be lifted in a loaded condition.

**904** Where a container has been constructed for lifting in a loaded condition a deflection test of the structure is to be carried out on the container in a loaded condition under the supervision of the Surveyors.

At this test the container is to be lifted with the cargo space loaded with a uniformly distributed load in three successive stages up to 1,25 times the specified maximum cargo load, and the ratio of the deflection to the length of the container is not to be greater than 1 to 1200.

The empty weight of the container and the maximum cargo load are to be clearly indicated on the container.

**905** Where a container is intended for carrying stacked with other similar containers, in addition to the lifting test in 904, the container is to be subjected to a downward load test equal to 1,8 times the maximum intended superimposed weight divided equally between the weight-bearing points.

The empty weight of the container, the maximum cargo load and the maximum superimposed stacking load are to be clearly indicated on the container.

**906** Where a number of identical containers are being built at the same time, the lifting test in 904 and (if applicable) the load test in 905, applied to one in every five containers may be accepted as sufficient.

**907** Where it is intended to use fork lift trucks in a container, the suitability of the floor for the maximum intended weight of truck and load may require to be tested on one container or on a prototype floor.

**908** A log book showing the particulars of the refrigeration of the container during each voyage is to be maintained, and this is to be made available to the Surveyor at each of the surveys required by 930.

Where the plant is operated by thermostatic control the intervals during which the machinery is working and at rest should be recorded occasionally, particularly during the period of maximum external temperature conditions of each voyage.

#### Class Notation

**909** The class notation will be in accordance with N 1 except that where the refrigerant condenser is air cooled the class notation shown in N 101 will give the maximum ambient temperature instead of the maximum sea temperature, e.g. "to maintain temp. minus 12°C with ambient temp. 40°C maximum."

Where the refrigerating machinery is electrically driven and dependent on the ship's generators for power, the class assigned will be subject to suitable electric power being available at all times when the container is loaded with refrigerated cargo.

#### Special Survey during Construction

**910** The requirements of N 2 are to be complied with in so far as they are applicable.

#### Refrigerating Plant

**911** The requirements of N 3 are to be complied with in so far as they are applicable, except as modified by the following paragraphs.

**912** Where two or more refrigerating units supply refrigeration to a container, the plant is to be capable of efficiently maintaining the minimum internal temperature under the maximum external conditions, to be specified in the class notation, when working 24 hours per day with any one of the refrigerating units out of action.

**913** When one refrigerating unit supplies refrigeration to a container, the unit is to be capable of efficiently maintaining the minimum internal temperature under the maximum external conditions, to be specified in the class notation, when working not more than 18 hours per day.

**914** Where the refrigerant condenser is air cooled and the maximum gas discharge pressure is above the maxima specified in N 326 and N 337, the design pressure is to be correspondingly increased.

**915** Where the design pressure is increased in accordance with 914, the test pressures specified in N 346 are to be increased proportionately.

**916** Where shell-and-tube type evaporators (brine coolers) and condensers can be readily removed, the space for the withdrawal and renewal of tubes in accordance with N 355 will not be required.

**917** Where the power for the container refrigerating unit on board ship is provided by an internal combustion engine installed with the unit, the container is to be carried on deck.

**918** Where an internal combustion engine is installed with the refrigerating unit for use only on land, the container may be carried in a well ventilated space below deck provided that before placing the container on board, the fuel tank is either drained or removed and stored in a safe place on the ship.



**Cargo Space**

919 When a container is of metal or timber panel construction the joints of the inner lining panels are to be made airtight and the joints of the outer lining panels are to be efficiently vapour sealed on both sides. Where it is not possible to apply the vapour seal on the inside of the outer panel joints the outer surface of the insulation is to be vapour sealed. All the materials used are to be suitable for the temperatures involved and without detriment to the cargoes carried.

Cargo doors, hinges and fastenings are to be of robust construction and the doors airtight.

920 Cargo battens or other suitable means are to be provided to ensure adequate space for circulation of air between the cargo and the linings.

921 The containers are to comply with the requirements of N 404 and N 405, N 407 and N 408, N 414, N 417 and N 418 in so far as they are applicable.

922 Drains of not less than 19 mm bore are to be provided from the cargo space and air cooler trays, and the drains are to be fitted with means of closure operable from outside the cargo space.

923 Thermometers are to be of approved type and position in the cargo space. Where thermometer tubes are provided the method of attachment is also to be approved.

**Tests after Completion**

924 Each completed container is to be tested in accordance with the requirements of N 5 in so far as they are applicable.

**Spare Gear**

925 Where two or more refrigerating units supply refrigeration to a container, the spare gear to be carried on the ship with container is to be in accordance with N 6 in so far as that Section is applicable.

926 Where a single refrigerating unit supplies refrigeration to a container, a complete spare compressor ready for fitting in place is to be carried on board the ship with the container, together with the spare gear required by 925, except those items which are included in the spare compressor.

927 Where a number of containers with identical refrigerating units are carried on a ship, one set of spare gear as required by 925 or 926, whichever is applicable, is to be carried on board for every ten or part of ten containers. This will apply up to a total of twenty containers carried but where the number exceeds this the additional spare gear required will be specially considered.

928 If at any time a group of containers is divided between two or more ships, spare gear as required by the foregoing paragraphs is to be carried on each ship.

**Containers not Constructed under Survey**

929 The requirements of N 7 are to be complied with in so far as they are applicable, except as amended by this Section.

**Periodical and other Surveys**

930 For the retention of the class assigned, periodical and other surveys are to be carried out in accordance with N 8 except as modified in the following paragraphs.

**Loading Port Surveys**

931 The requirements of N 810 and N 812 are to be complied with and, in addition, the Surveyor is to satisfy himself that the container is placed on board in such a position as to provide free access to it by the ship's personnel for servicing the refrigerating plant and noting the temperatures; and, where the refrigerant condenser is air cooled, to allow free flow of fresh air to, and heated air from, the condenser.

932 Generating plant supplying power and the cables and connections to the refrigerating machinery are to be examined generally.

933 The Surveyor is also to satisfy himself that the drains from the cargo space and air cooler trays are clear and the closing devices are in order.

934 Where an Owner desires a Loading Port Survey of a container which is to be loaded with refrigerated cargo ashore instead of on board the ship, the particular circumstances will require to be specially considered.

**Running Surveys**

935 The requirements of N 815 to N 837 are to be complied with so far as they are applicable. In addition, the cargo space and air cooler drains and their closing appliances are to be examined.

**First Special Survey**

936 The requirements of N 839 to N 848 are to be complied with so far as they are applicable.

937 Sufficient covering and insulation is to be stripped from the floor of the container to permit the condition of the insulation, grounds and structure to be ascertained.

**Subsequent Special Surveys**

938 The requirements of N 849 to N 857 are to be complied with so far as they are applicable, and in addition, those of 937.



# Chapter P

## MATERIALS FOR SHIP CONSTRUCTION

### General

Materials used in the construction and for the equipment of ships are to be manufactured and tested in accordance with the requirements contained in the following Sections of this Chapter:—

- Section 1. General requirements for rolled steel products.
- „ 2. Mild steel for hull structures.
  - „ 3. Higher tensile steel for hull structures.
  - „ 4. Steel rivet bars and manufactured rivets.
  - „ 5. Steel castings.
  - „ 6. Steel forgings.
  - „ 7. Steel anchors.
  - „ 8. Chain cable and steering chains.
  - „ 9. Steel wire ropes for standing rigging, towlines and mooring ropes.
  - „ 10. Fibre ropes.
  - „ 11. Approval of electrodes and combinations of consumables for welding in hull construction.
  - „ 12. Aluminium alloy plates, bars and sections.
  - „ 13. Aluminium alloy rivets.
  - „ 14. Welding of aluminium alloys.

With a few exceptions, the mechanical properties specified are in SI units only, but alternative units may be used for acceptance testing. In such cases, the specified values are to be converted in accordance with the appropriate Table included in “Appendix 1, Conversion Tables for Use with Chapters P and Q”, following Chapter Q.

### Section 1

#### GENERAL REQUIREMENTS FOR ROLLED STEEL PRODUCTS

##### Scope

101 (a) This Section gives the general requirements for steel plates, sections, bars, tubes and other hollow sections intended for use in hull construction.

These items are to be manufactured and tested in accordance with the general requirements given in this Section, together with the specific requirements contained in P 2 or P 3.

These requirements are primarily intended to apply to steel not exceeding 50 mm in thickness. For greater thicknesses, certain variations in the requirements may be allowed or required in particular cases after consideration of the technical circumstances involved.

(b) Steel is to be manufactured at works approved by the Committee for the grade, or grades, ordered. A list of approved manufacturers is given in Appendix 2 following Chapter Q.

##### Manufacture

102 (a) Steel is to be manufactured by the open hearth, electric furnace or oxygen processes or by other processes approved by the Committee. An oxygen process is defined as a process in which molten iron contained in a basic lined converter is refined by directing a jet of high purity gaseous oxygen on the surface of the hot metal.

The steel making practice is to be such as to minimize the included non-metallic content of the finished steel. Acceptable deoxidation practices are given under the specific requirements in P 2 or P 3.

(b) The steel is to be cast in metal ingot moulds or by an approved continuous casting process. The size of the ingot or of the continuous cast billet or slab is to be proportional to the dimensions of the final product in order that the amount of mechanical work will be adequate to ensure a satisfactory steel structure in the finished product. Provision is also to be made for sufficient discard to be taken from the top and bottom of each ingot to ensure soundness in the portion used for further processing. Periodically, and at the Surveyor's discretion, sulphur prints or other suitable proving tests may be required to demonstrate that this has been fulfilled.

##### Chemical Analysis

103 The chemical composition is to be determined by the maker in an adequately equipped and competently staffed laboratory on samples taken from each ladle of each cast. The maker's analysis will be accepted but may be subject to occasional checks if required by the Surveyors.



**Heat Treatment**

104 All materials are to be supplied in the condition specified, or permitted, in P 204 or P 304. Where it is proposed to use a controlled rolling procedure, as a substitute for normalizing, full details are to be submitted for approval.

Heat treatment is to be carried out in properly constructed furnaces which are efficiently maintained, have adequate means for temperature control and are fitted with pyrometers which measure the temperature of the furnace charge. The furnace dimensions must permit the whole item being uniformly heated to the necessary temperature.

**Test Material**

105 (a) Sufficient test material is to be provided for the preparation of the tests detailed in P 2 or P 3. It is, however, in the interest of manufacturers to provide additional material for any re-tests which may be necessary, as insufficient or unacceptable test material may be a cause for rejection.

All materials in a batch presented for acceptance tests are to be of the same product form, e.g. plates, flats, sections, etc., from the same cast and in the same condition of supply.

The test material from which the test pieces are cut is to be treated together with and in the same way as the material which it represents. The test pieces are not to be separately heat treated in any way.

All test material is to be selected and identified by the Surveyor or an authorized deputy. These identification marks are to be maintained during the preparation of the test pieces.

(b) The test pieces are to be taken from the following positions.

- (i) For plates and plain flats more than 400 mm wide, the test pieces are to be taken from a position approximately one-quarter of the width from the edge of the piece, *see* Fig. P 1.1 (a).

When the width is more than 600 mm, the tensile test pieces are to be cut with their longitudinal axes transverse to the final direction of rolling.

The impact test pieces are to be cut with their longitudinal axes parallel to the final direction of rolling.

- (ii) For plain flats 400 mm or less in width, bulb flats and other sections, the test pieces are to be taken from a position approximately one-third of the width from the outer edge, *see* Figs. P 1.1 (b),

P 1.1 (c), P 1.1 (d). Alternatively, in the case of channels, beams, or bulb angles, the test pieces may be taken from a position approximately one-quarter of the width from the centreline of the web, *see* Fig. P 1.1 (c).

The tensile test pieces may be cut with their longitudinal axes either parallel or transverse to the final direction of rolling.

The impact test pieces are to be cut with their longitudinal axes parallel to the final direction of rolling.

- (iii) For bars and other similar products, the test material is to be taken so that the axis of the test piece is parallel to the direction of rolling. For small sizes, the tensile test piece may consist of a suitable length of the full cross-section of the product. For larger sizes, the test material is to be taken so that the axis of the test piece lies as nearly as possible to the following positions:—

for non-cylindrical sections, at one-third of the half-diagonal from the outside, and

for cylindrical sections, at one-third of the radius from the outside, *see* Fig. P 1.1 (e).

- (c) The tensile test pieces are to be prepared as follows.

- (i) Standard tensile test piece. This test piece is to be of a rectangular cross-section with a thickness equal to that of the material from which it is cut, a width of 25 mm and a gauge length of 200 mm. The parallel length is to be not less than 225 mm. The ends of the test specimen may be increased in width to suit the grips of the machine, the transition between the different widths being made with a gentle curve.

- (ii) Proportional tensile test piece. This test piece is to have the gauge length equal to 5.65 times the square root of the cross-sectional area and, subject to agreement, may be used instead of the standard test piece.

- (iii) Alternative tensile test piece. Tensile test pieces of other dimensions may be used provided that the cross-sectional area is not less than 160 mm<sup>2</sup> and that the equivalent elongation value is calculated in accordance with 106 (b) (ii).

- (d) The impact test pieces are to be of the Charpy V-notch type machined to the dimensions and tolerances given in Table P 1.1. Standard test pieces 10 mm square are to be used, except where the thickness of the material



does not permit this size of test piece being prepared. In such cases the largest possible size of subsidiary test piece is to be prepared with the notch cut on the narrow face. Alternatively, for material of suitable thickness, the rolled surfaces may be retained so that the test piece width will be the full thickness of the material. The prescribed dimensions are to be carefully and systematically checked. The notch is to be cut in a face of the test piece which was originally perpendicular to the rolled surface.

The position of the notch is to be not nearer than 25 mm to a flame-cut or sheared edge.

(e) Definitions

*Piece or rolled length* in respect of plates, bars and sections, is the rolled product from a single slab, bloom or ingot if this is rolled directly into plates, bars or sections.

*Item* is a single plate, bar, section or component as delivered.

*Test material or test block* is the material from which the test piece is prepared.

*Test piece* is the portion of the test material or test block on which the actual test is carried out.

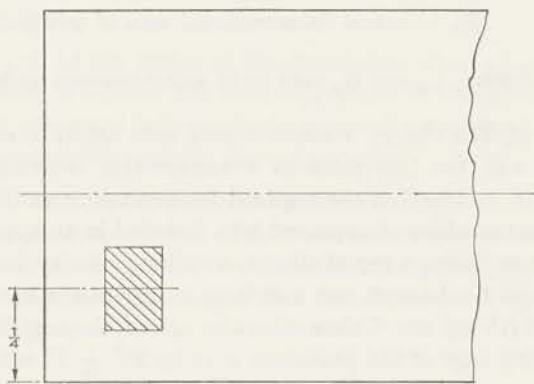


FIG. P 1.1 (a) PLATES AND FLATS

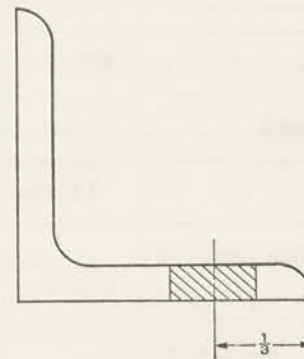


FIG. P 1.1 (b) ANGLES

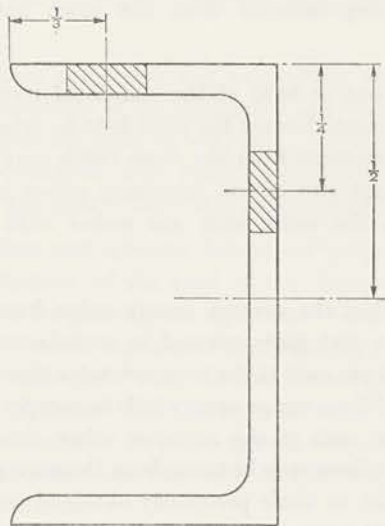


FIG. P 1.1 (c) CHANNELS AND BEAMS

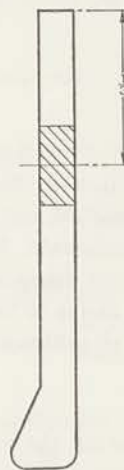


FIG. P 1.1 (d) BULB FLATS

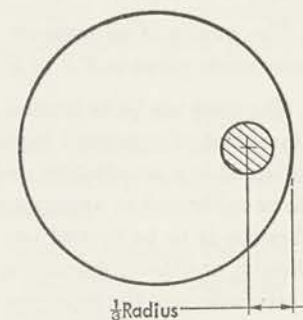


FIG. P 1.1 (e) ROUNDS

TABLE P 1.1

**DIMENSIONS AND TOLERANCES FOR  
CHARPY V-NOTCH TEST PIECES**

DIMENSIONS				NOMINAL DIMENSION	TOLERANCE
Length	...	...	...	55 mm	±0,60 mm
Width	...	Standard		10 mm	±0,11 mm
		Subsidiary		7,5 mm	±0,11 mm
		„		5,0 mm	±0,05 mm
Thickness	...	...	...	10 mm	±0,11 mm
Angle of notch	...	...		45°	±2°
Depth below notch	...			8 mm	±0,11 mm
Root radius	...	...	...	0,25 mm	±0,025 mm
Distance of notch from end of test piece	...	...	...	27,5 mm	±0,42 mm
Angle between plane of sym- metry of notch and longi- tudinal axis of test piece				90°	±2°

**Mechanical Tests**

106 (a) All prescribed mechanical tests are to be carried out by the manufacturer before the material is despatched. They are to be witnessed by the Surveyor or by an authorized deputy.

The results of all tests are to comply with the specific requirements given in P 2 or P 3.

The tests are to be carried out by competent personnel on machines of approved types. The machines are to be maintained in a satisfactory and accurate condition and are to be re-calibrated at approximately annual intervals. This calibration is to be carried out by a Nationally recognized authority, or other organization of standing, and is to be to the satisfaction of the Surveyor. A record of all calibrations is to be kept available in the test house.

(b) (i) For the purpose of these requirements, the yield stress is to be regarded as the value of stress determined from the load at which a hesitation or drop of the load pointer is first observed. The load taken is usually the maximum as recorded by the slave pointer during yield extension.

(ii) Minimum elongation values for the standard test piece and the proportional test pieces are given in Tables P 2.2 and P 3.3. For test pieces of other dimensions, the equivalent elongation values are to be calculated using the following formula:—

$$E = \frac{n}{2} \left( \frac{L_0}{\sqrt{S_0}} \right)^{0,40}$$

where E = equivalent percentage elongation for a test piece with a gauge length of  $5,65 \sqrt{S_0}$ .

n = actual measured percentage elongation of test piece,

$L_0$  = actual gauge length of test piece,

$S_0$  = actual cross-sectional area of test piece.

NOTE.  $L_0$  and  $S_0$  may be in any consistent units.

(c) The Charpy V-notch impact tests are to be carried out with the test piece at a temperature controlled to within  $\pm 1$  degC of the required temperature, on a Charpy impact machine of approved type installed in an approved manner having a gap of 40 mm, a striking velocity between 4,5 and 6 m/second, and a striking energy of not less than 147 J (15 kgf m). Unless otherwise agreed, the angle of the striking edge of the pendulum is to be  $30^\circ \pm 1^\circ$  with the edge rounded to a radius not exceeding 2,5 mm.

(d) (i) When the tensile test from the first piece selected in accordance with 105 fails to meet the requirements, two further tensile tests may be made from the same piece. If both these additional tests are satisfactory, this piece and the remaining material from the same batch may be accepted.

(ii) If one or both of the additional tests referred to above are unsatisfactory the piece is to be rejected, but the remaining material from the same batch may be accepted provided that two of the remaining pieces in the batch, selected in the same way, are tested with satisfactory results.

(iii) When the average energy value from the impact tests on the first piece selected in accordance with 105 is less than 85 per cent of the required value this piece is to be rejected. If the average energy fails to comply by not more than 15 per cent of the required value, three additional impact test pieces may be taken from the same piece and the results added to those previously obtained to form a new average. If this new average complies with the requirements, the first piece selected and the remaining material in the batch may be accepted. If the new average is less than that required, the first piece selected is to be rejected.



(iv) When the first piece selected is rejected, additional sets of impact test pieces may be taken from two further pieces selected from the same batch. These are to be tested as above and, if satisfactory results are obtained from both sets of tests, these pieces and the remaining pieces in the batch may be accepted. If one or both of these additional sets of tests do not give satisfactory results, the batch is to be rejected.

(v) If any test piece fails because of faulty preparation, visible defects, or (in the case of a tensile test) because of fracturing outside the middle-half of the gauge length, the defective test piece may, at the Surveyor's discretion, be discarded and replaced by an additional test piece of the same type.

(vi) At the option of the steelmaker, when a batch of material is rejected the remaining pieces in the batch may be re-submitted individually for test, and those pieces which give satisfactory results may be accepted.

(vii) At the option of the steelmaker, rejected material may be re-submitted after heat treatment, or re-heat treatment, or may be re-submitted as another grade and may then be accepted, provided that the required tests are satisfactory.

### Inspection

**107** (a) The manufacturers are to afford the Surveyors all necessary facilities and access to all relevant parts of the works to enable them to verify that the approved process is adhered to, for the selection of test material, the witnessing of tests and the examination of material as required by the Rules.

(b) Surface inspection and verification of dimensions are the responsibility of the steelmaker and are to be carried out on all material prior to despatch. Acceptance by the Surveyors of material later found to be defective shall not absolve the steelmaker from this responsibility.

(c) Surface and internal defects not prejudicial to the proper application of the steel is not, except by special agreement, to be grounds for rejection. Where necessary, the use of special techniques (radiography, ultrasonics, magnetic particle tests, etc.) for the detection of harmful surface and internal defects, together with appropriate acceptance standards, is to be agreed between the ship-builder, steelmaker and Surveyor and is to be expressly stated in the order.

(d) In the event of any material proving unsatisfactory during subsequent working, machining or fabricating, such material is to be rejected notwithstanding any previous certification.

(e) The minus tolerance in the thickness of plates and sections from those given on the approved plans is not to exceed that shown in Table P 1.2.

TABLE P 1.2

NOMINAL THICKNESS $t$			TOLERANCE
		mm	mm
Not exceeding ...	...	15,0	0,4
Not exceeding ...	...	45,0	$(0,02t+0,1)$
Over ...	...	45,0	1,0

The general standard as laid down by the Rules is to be maintained.

The thickness of plates is to be measured at positions which are approximately 40 mm from an edge and 100 mm from a corner.

### Rectification of Defects

**108** (a) Surface defects may be removed by local grinding provided that the thickness is in no place reduced to less than 93 per cent of the nominal thickness but in no case by more than 3 mm.

The extent of such rectification is to be agreed in each case with the Surveyors and is to be carried out under their supervision, unless otherwise agreed.

(b) Surface defects which cannot be dealt with as above may be repaired by chipping or grinding followed by welding, subject to the Surveyors' consent and under their supervision, provided that:—

- after removal of the defect and before welding, the thickness of the item is in no place reduced by more than 20 per cent,
- the welding is carried out by an approved procedure, by competent operators with approved electrodes, and the welding is ground smooth to the correct nominal thickness,
- subsequent to the finished grinding, the item may be required to be normalized or otherwise heat treated at the Surveyor's discretion.

### Identification

**109** (a) The steelmaker is to adopt a system for the identification of ingots, slabs and finished items which will enable the material to be traced to its original cast, and the Surveyors are to be given full facilities for so tracing the material when required.



(b) Every finished item is to be clearly marked by the maker in at least one place with the Society's brand and the following particulars:—



- (i) Agreed identification mark for the grade of steel.
- (ii) Name or initials to identify the steelworks.
- (iii) Number and/or initials to identify the piece.
- (iv) If required by the purchaser, his order number or other identification mark.

Where a number of light materials are securely fastened together in bundles, the manufacturer may brand only the top piece of each bundle, or alternatively, a firmly fastened durable label containing the brand may be attached to each bundle.

(c) In the event of any material bearing the Society's brand failing to comply with the test requirements, the brand is to be unmistakably defaced.

#### Documentation

110 (a) The Surveyor is to be supplied with at least two copies of the test certificate or shipping statements for all accepted material, which documents should be separate for each grade of steel. The documents shall contain, in addition to the description, dimensions, etc., of the material, the following particulars:—

- (i) Purchaser's order number and, if known, ship number for which material is intended.
- (ii) Address to which material is despatched.
- (iii) Identification of the cast and piece.
- (iv) Identification of the steelworks.
- (v) Identification of the grade of steel.
- (vi) Ladle analysis which is to include at least C, Mn, Si, S and P.
- (vii) Condition of supply when other than as rolled, e.g. normalized, or controlled rolled.

(b) Before the test certificates or shipping statements are signed by the Surveyor, the steelmaker is required to furnish him with a written declaration stating that the material has been made by an approved process, and that it has been subjected to and has withstood satisfactorily the required tests in the presence of the Surveyor or an authorized deputy. The following form of declaration will be accepted if stamped or printed on each test certificate or shipping statement with the name of the steelworks and initialled for the maker by an authorized official:—

"We hereby certify that the material herein described has been made by the.....process (process to be stated) approved by and in accordance

with the Rules of Lloyd's Register of Shipping for Grade.....steel, and is that which has been tested in the presence of the Society's representative with satisfactory results."

(c) When steel is not produced at the works at which it is rolled, a certificate is to be supplied to the Surveyor at the rolling mill stating the process by which it was manufactured, the name of the manufacturer who supplied it, the number of the cast from which it was made and the ladle analysis. The works at which the steel was produced must be approved by the Committee.

## Section 2

### MILD STEEL FOR HULL STRUCTURES

#### Scope

201 Plates, sections, bars, tubes and other hollow sections in mild steel intended for use in hull construction are to be manufactured and tested in accordance with the requirements of this Section and the general requirements in P 1.

For information regarding requirements for the application of different grades of steel, see paragraphs D 413, D 414, D 427, D 511, D 512, D 4008, D 4009, and the *Rules for Ships for Liquefied Gases*.

#### Manufacture

202 The method of deoxidation is to be in accordance with that given in Table P 2.2.

#### Chemical Composition

203 The chemical composition is to comply with the requirements given in Table P 2.2.

#### Heat Treatment

204 All materials are to be supplied in a condition complying with the requirements given in Table P 2.1.

Where alternative conditions are permitted, these are at the option of the steelmaker unless otherwise expressly stated in the order for the material.

#### Test Material

205 (a) For each batch presented, one tensile test is to be made from one piece unless the weight of finished material is greater than 40 tonnes, in which case one extra test is to



TABLE P 2.1 HEAT TREATMENT

GRADE AND THICKNESS	CONDITION OF SUPPLY
A. All thicknesses	As rolled, normalized or controlled rolled
B. All thicknesses	„ „
D. Thicknesses up to and including 35 mm	„ „
D. Thicknesses over 35 mm (See also Table P 2.2, Note 2)	Normalized or controlled rolled <i>see Note</i>
E. All thicknesses	Normalized <i>see Note</i>

NOTE. Sections in Grades D and E steels may be supplied in the as-rolled condition provided satisfactory results are consistently obtained from Charpy V-notch impact tests.

be made from a different piece from each 40 tonnes or fraction thereof. Additional tests are to be made for every variation of 5 mm in the thickness of plates from the same cast. For sections and bars, additional tests are to be made for every variation of 20 per cent in dimensions.

(b) For Grade A steel, Charpy V-notch impact tests are not required for routine acceptance test purposes.

For Grades B and D steels, one set of three impact test pieces is to be made from the thickest piece in each batch presented, unless the weight of finished material is greater than 40 tonnes, in which case one extra set of tests is to be made from a different piece from each 40 tonnes or fraction thereof.

For Grade D steel over 35 mm in thickness where an approved controlled rolling is used as a substitute for normalizing, impact tests are to be taken as above except that one set is required from each 20 tonnes or fraction thereof.

For plates in Grade E steel, one set of three test pieces is to be made from each piece. For sections in Grade E steel, one set of three test pieces is to be made from material representative of the rolled product from each ingot.

#### Mechanical Tests

206 The results of all tensile tests and the average energy value from each set of three impact tests are to comply with the value given in Table P 2.2.

#### Inspection

207 Inspection is to be carried out in accordance with P 107.

#### Rectification of Defects

208 The rectification of defective areas is to be carried out by procedures in accordance with P 108.

#### Identification

209 Every finished item is to be clearly marked as required by P 109 (b) and the marking is to be surrounded by a clear ring in white paint.

Where the name of the steelworks is embossed on finished sections, only the Society's brand and items (i), (iii) and (iv) of P 109 (b) need be surrounded by white paint.

Where a number of light materials are bundled, one end of each piece is to be marked with white paint.

#### Documentation

210 The steelmaker is to supply the documentation detailed in P 110.

If the steel is of rimming quality, this is to be stated on the test certificate or shipping statement.

Where appropriate, the ladle analysis is also to include the aluminium content.

### Section 3

#### HIGHER TENSILE STEEL FOR HULL STRUCTURES

##### Scope

301 (a) Plates, sections, bars, tubes and other hollow sections in higher tensile steel, i.e. with a specified minimum yield stress of 265 N/mm<sup>2</sup> or higher, which are intended for use in hull construction, are to be manufactured and tested in accordance with the requirements of this Section and the general requirements in P 1.

TABLE P 2.2

**CHEMICAL COMPOSITION AND MECHANICAL PROPERTIES FOR PRODUCTS NOT EXCEEDING  
50 mm IN THICKNESS**

(Requirements for greater thicknesses are subject to agreement. See P 101 (a))

GRADE	A	B	D	E
DEOXIDATION	Any method (For rimmed steel see Note 1)	Any method except rimmed steel	Fully killed, fine grain practice (Aluminium treated) see Note 2	Fully killed, fine grain practice (Aluminium treated)
CHEMICAL COMPOSITION (ladle analysis)				
Carbon	0,23% max. See Notes 3 and 5	0,21% max. 0,80% min. } Notes 4 and 5	0,21% max. 0,70% to 1,40% } Notes 5 and 6	0,18% max. 0,70% to 1,50% } Note 5
Manganese	0,50% max.	0,50% max.	0,10% to 0,50% max.	0,10% to 0,50%
Silicon	0,050% max.	0,040% max.	0,040% max.	0,040% max.
Sulphur	0,050% max.	0,040% max.	0,040% max.	0,040% max.
Phosphorus	—	—	0,015% min. Note 7	0,015% min. Note 7
Aluminium (acid soluble)	—	—	—	—
TENSILE TEST				
Yield Stress (min.) N/mm <sup>2</sup>	230 (Note 8)	230 (Note 8)	235	235
TENSILE STRENGTH N/mm <sup>2</sup>	400 to 490	400 to 490	400 to 490	400 to 490
ELONGATION % min. Standard Test Piece Thickness (mm)				
More than				
Less than or equal to				
5	15	15	15	15
10	16	16	16	16
15	17	17	17	17
20	18	18	18	18
25	19	19	19	19
35	20	20	20	20
35	21	21	21	21
PROPORTIONAL TEST PIECE				
Gauge Length $5,65\sqrt{S_0}$	22	22	22	22
IMPACT TEST (LONGITUDINAL)				
Test Temperature	—	0°C	0°C	—40°C
Minimum Average Energy	—	J	J	J
Width of test piece				
10 mm	—	27	47	27
7,5 mm	—	23	39	23
5,0 mm	—	19	31	19
(See Note 9)				



## NOTES. TABLE P 2.2

1. For Grade A, rimming steel may be accepted up to 12,5 mm thick inclusive, provided that it is stated on the test certificates or shipping statements to be rimming steel and is not excluded by the purchaser's order.
2. Other deoxidation methods, except rimmed steel, may be used for Grade D in thicknesses up to and including 35 mm, provided that in thicknesses over 25,5 mm the condition of supply for plates is either normalized or controlled rolled. In such cases, the requirements for fine grain practice and the minimum silicon and aluminium contents do not apply.
3. For Grade A in thicknesses over 12,5 mm, the manganese content is to be not less than 2,5 times the carbon content.
4. For Grade B, when the silicon content is 0,10 per cent or more (killed steel) the minimum manganese content may be reduced to 0,60 per cent.
5. For all grades the sum of carbon content plus  $1/6$  of the manganese content shall not exceed 0,40 per cent.
6. For Grade D when the thickness is 25,5 mm or less, the minimum manganese content may be reduced to 0,60 per cent.
7. The total aluminium content may be determined instead of the acid soluble content. In such cases the total aluminium content is to be not less than 0,020 per cent.
8. For Grades A and B over 25,5 mm in thickness, the minimum yield stress is 220 N/mm<sup>2</sup>.
9. Where non-standard subsidiary impact test pieces are used, the minimum value may be obtained by interpolation.

(b) Steels differing from the requirements of this Section in respect of chemical composition, deoxidation practice, heat treatment or mechanical properties, may be accepted subject to special approval by the Committee. Such steels are to be given a special designation.

#### Manufacture

**302** Grades AH and DH steels of each strength level may be made, at the option of the steelmaker, as semi-killed or silicon-killed steel, but rimming steel is not permitted.

Grade EH steel of each strength level is to be silicon-killed.

#### Chemical Composition

**303** (a) The chemical composition for all grades of steel is to comply with the requirements of Table P 3.1.

(b) In order to ensure satisfactory weldability under shipyard conditions, a maximum carbon equivalent is to be agreed between the shipbuilder and the steelmaker when the steel is ordered. *See* D 3219 (a), quoted at the end of this Section.

#### Heat Treatment

**304** All materials are to be supplied in a condition complying with the requirements given in Table P 3.2.

Where alternative conditions are permitted, these are at the option of the steelmaker unless otherwise expressly stated in the order for the material.

#### Test Material

**305** (a) For each batch presented, one tensile test is to be made from one piece unless the weight of finished material is greater than 40 tonnes, in which case one extra test is to be made from a different piece from each 40 tonnes or fraction thereof. Additional tests are to be made for every variation of 5 mm in the thickness of plates from the same cast. For sections and bars, additional tests are to be made for every variation of 20 per cent in dimensions.

(b) Charpy V-notch impact tests are to be made in accordance with the requirements given in Table P 3.2 for the optional grain refining practices and conditions of supply used by the steelmaker.

#### Mechanical Tests

**306** Provision is made for material to be supplied in four strength levels with differing values of specified minimum yield stress, i.e. 27S, 32, 34S or 36. The strength levels 27S and 34S are additional to the agreed IACS requirements for higher tensile hull structural steels, and

accordingly have been additionally designated by the letter "S".

Each strength level is further subdivided into three Grades, AH, DH and EH, which signify differing levels of notch toughness.

For the designation to identify fully a steel and its properties, the appropriate letters should precede the strength level numbers as shown in Table P 3.3.

The results of all tensile tests and the average energy value from each set of three impact tests are to comply with the values shown in Table P 3.3. The impact energy values specified for each grade are to be obtained at the test temperature given in the Table.

TABLE P 3.1

	MIN. %	MAX. %	NOTES
Carbon		0,18	
Manganese	0,90	1,60	1
Silicon		0,50	2
Sulphur		0,040	
Phosphorus		0,040	
GRAIN REFINING ELEMENTS			
Aluminium (acid soluble)	0,015		3 & 4
Niobium	0,015	0,05	4
Vanadium	0,03	0,10	4
RESIDUAL ELEMENTS			
Copper		0,35	
Chromium		0,20	
Nickel		0,40	
Molybdenum		0,08	
Maximum carbon equivalent to be agreed, <i>see</i> P 303 (b).			

#### NOTES

1. For Grade AH steels in all strength levels and for Grades DH and EH steels in strength level 27S, the specified minimum manganese content is 0,70 per cent.

2. The Grade EH steels for each strength level are to be killed and are to contain not less than 0,10 per cent silicon.

3. The total aluminium content may be determined instead of the acid soluble content. In such cases the total aluminium content is to be not less than 0,020 per cent.

4. For Grade AH steels in all strength levels and for Grade DH 27S steel, the addition of grain refining elements is at the option of the steelmaker.

All other steels are to contain aluminium, niobium, vanadium, or other suitable grain refining elements, either singly or in any combination. When used singly, the steel is to contain the specified minimum content of the grain refining element. When used in combination, the specified minimum content of each element is not applicable.



TABLE P 3.2

## CONDITION OF SUPPLY AND IMPACT TEST REQUIREMENTS

GRAIN REFINING PRACTICE USED	THICKNESS	CONDITION OF SUPPLY	IMPACT TEST REQUIREMENT	NOTE
AH 27S    AH 32    AH 34S    AH 36 No grain refining elements added	≤12,5 mm	As Rolled	Not Required	1
		Controlled Rolled	Not Required	1
		Normalized	Not Required	1
	> 12,5 mm    ≤35 mm	As Rolled	Required	2
		Controlled Rolled	Required	2
		Normalized	Required	2
	> 35 mm	Normalized	Required	2
		Controlled Rolled (Notes 4 & 7)	Required (Note 5)	3
	Niobium or Aluminium + Niobium	≤12,5 mm	As Rolled	Not Required
Controlled Rolled			Not Required	1
> 12,5 mm		Normalized	Not Required	1
		Controlled Rolled (Note 7)	Required	3
Vanadium or Aluminium or Aluminium + Vanadium	≤12,5 mm	As Rolled	Not Required	1
		Controlled Rolled	Not Required	1
		Normalized	Not Required	1
	> 12,5 mm    ≤35 mm	As Rolled	Required	2
		Controlled Rolled	Required	2
		Normalized	Not Required	1
	> 35 mm	Normalized	Not Required	1
Controlled Rolled (Notes 4 & 7)	Required (Note 5)	3		
DH 27S    DH 32    DH 34S    DH 36 Niobium or Aluminium + Niobium	≤12,5 mm	As Rolled	Required	2
		Controlled Rolled	Required	2
		Normalized	Required	2
	> 12,5 mm	Normalized	Required	2
		Controlled Rolled (Note 7)	Required	3
	≤25,5 mm	As Rolled	Required	2
		Controlled Rolled	Required	2
		Normalized	Required	2
> 25,5 mm	Normalized	Required	2	
	Controlled Rolled (Note 7)	Required	3	
EH 27S    EH 32    EH 34S    EH 36 All practices	All thicknesses	Normalized (Note 7)	Required	6

NOTES. TABLE P 3.2

1. Charpy V-notch tests are not generally required, provided satisfactory results are obtained from occasional check tests selected by the Surveyor.

2. One set of three Charpy V-notch tests is to be made from the thickest piece in each batch presented unless the weight of finished material is greater than 40 tonnes, in which case one extra set of tests is to be made from a different piece from each 40 tonnes, or fraction thereof.

3. Charpy V-notch tests are to be made as required by Note 2, except that one set of tests is required from each 20 tonnes, or fraction thereof. Controlled rolling procedures are to be specially approved as required by P 104.

4. For Grade AH 27S only, when the thickness exceeds 35 mm, the condition of supply may be as rolled.

5. For Grade AH 27S only, when supplied in the as-rolled or controlled rolled condition, Charpy V-notch tests are required and, in general, will be acceptable in accordance with Note 2.

6. For plates, one set of three Charpy V-notch tests is to be made from each piece. For sections, one set of three tests is to be made from material representative of the rolled product from each ingot.

7. Sections in all Grade AH, DH and EH steels may be supplied in the as-rolled condition provided satisfactory results are consistently obtained from Charpy V-notch impact tests.



TABLE P 3.3

## MECHANICAL PROPERTIES FOR PRODUCTS NOT EXCEEDING 50 mm IN THICKNESS

(Requirements for greater thicknesses are subject to agreement. See P 101 (a))

GRADE AND STRENGTH LEVEL DESIGNATION		AH 27S DH 27S EH 27S	AH 32 DH 32 EH 32	AH 34S DH 34S EH 34S	AH 36 DH 36 EH 36
YIELD STRESS	N/mm <sup>2</sup> (min.)	265	315	340	355
TENSILE STRENGTH	N/mm <sup>2</sup>	400 to 510	440 to 590	610 max.	490 to 620
RATIO : $\frac{\text{Yield stress}}{\text{Tensile strength}}$		—	—	0,85 max.	—
ELONGATION % min. Standard Test Piece Thickness (mm)					
More than	Less than or equal to				
	5	15	15	15	14
5	10	16	16	16	15
10	15	17	17	17	16
15	20	18	18	18	17
20	25	19	19	19	18
25	35	20	20	20	19
35		21	21	21	20
PROPORTIONAL TEST PIECE Gauge Length $5,65\sqrt{S_0}$		22	22	22	21
IMPACT TEST (LONGITUDINAL) Test Temperature Grade AH 0°C DH minus 20°C EH minus 40°C					
Minimum Average Energy		J 27	J 31	J 34	J 34

**Inspection**

307 Inspection is to be carried out in accordance with P 107.

**Rectification of Defects**

308 The rectification of defective areas is to be carried out by procedures in accordance with P 108 and as appropriate for the steel.

**Identification**

309 Every finished item is to be clearly marked as required by P 109 (b). The agreed identification mark is to

be the grade and strength level designation as given in Table P 3.3.

Steels which have been specially approved and which differ from these requirements are to have the letter S after the agreed identification mark.

This marking is to be surrounded by a clear ring in green paint.

Where the name of the steelworks is embossed on finished sections, only the Society's brand and items (i), (iii) and (iv) of P 109 (b) need be surrounded by green paint.

Where a number of light materials are bundled, one end of each piece is to be marked with green paint.

**Documentation**

**310** The steelmaker is to supply the documentation detailed in P 110.

The identification required by P 110 (iv) is to be the grade and strength level designation as given in Table P 3.3.

The ladle analysis is also to include the grain refining elements and the specified maximum carbon equivalent.

For other specially approved steels, the agreed identification mark, the specified minimum yield stress and, if applicable, the content of alloying elements are to be stated on the test certificate or shipping statement.

**Extract from Chapter D for reference**

**D 3219** (a) When the carbon equivalent, calculated from the ladle analysis and using the formula given below, is in excess of 0,45%, approved low hydrogen higher tensile electrodes and preheating are to be used. When the carbon equivalent is above 0,41% but is not more than 0,45%, approved low hydrogen higher tensile electrodes are to be used but preheating will not generally be required except under conditions of high restraint or low ambient temperature. When the carbon equivalent is not more than 0,41%, any type of approved higher tensile electrodes may be used and preheating will not generally be required except as above.

Carbon equivalent=

$$C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15}$$

This formula is applicable only to steels which are basically of the carbon-manganese type containing minor quantities of grain refining elements, for example, niobium, vanadium or aluminium. The proposed use of low alloy steels will be subject to special consideration.

**Section 4****STEEL RIVET BARS AND MANUFACTURED RIVETS****Testing of Material**

**401** All material from which rivets are manufactured is to be tested.

Rivets are not to be manufactured from steel in which the sulphur segregates and other non-metallic substances are concentrated in the core. To ensure this, a sulphur print is to be taken from the material of each cast, and where the weight of bars as rolled from one cast exceeds 10 tonnes, additional sulphur prints may be taken.

**P 310 - P 409**

**Number of Tests**

**402** One tensile test piece is to be taken from each cast used for rivet bars; but where the weight of bars as rolled from one cast exceeds 10 tonnes an additional tensile test is to be made from each further 10 tonnes or portion thereof.

**403** One dump test is to be made for each tensile test.

**Tensile Test Pieces**

**404** Rivet bars may be tested in full section or may be machined to a convenient size provided the cross-sectional area is not less than 160 mm<sup>2</sup>. Where a gauge length other than  $5,65\sqrt{S_0}$  is used, the equivalent elongation is to be calculated using the formula given in P 106 (b) (ii).

**Tensile Test**

**405** The tensile strength of steel rivet bars is to be within the limits of 400 and 490 N/mm<sup>2</sup> and the elongation on a gauge length of  $5,65\sqrt{S_0}$  is to be not less than 26 per cent.

**Dump Test**

**406** Short lengths, equal to twice their diameter, cut from the rivet bars shall, when cold, withstand without fracture being compressed to half their length.

**Manufactured Rivets**

**407** Rivets selected by the Surveyor from the bulk are to withstand the tests described in 408 to 410.

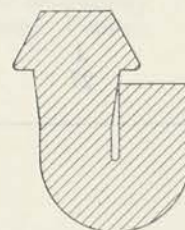


FIG. P 4.1

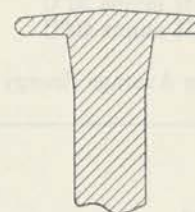


FIG. P 4.2

**408** The rivet shanks are to be bent cold, and hammered until the two parts of the shank touch in the manner shown in Fig. P 4.1, without fracture on the outside of the bend.

**409** The rivet heads are to be flattened, while hot, in the manner shown in Fig. P 4.2, without cracking at the edges. The heads are to be flattened until their diameter is 2,5 times the diameter of the shank.



410 In the case of steel rivets, samples are to be selected by the Surveyor for examination by means of sulphur prints, to ensure that the material is free from marked central segregation.

## Section 5

### STEEL CASTINGS

#### Scope

501 Cast steel sternframes, rudder frames, rudder stocks, propeller shaft brackets and other steel castings intended for use in hull construction are to be manufactured and tested in accordance with the requirements of this Section.

Where it is proposed to use low alloy steel castings, particulars of the chemical composition, mechanical properties and heat treatment are to be submitted for approval. These castings are to be tested and accepted on the basis of the approved specification and such other tests as may be considered necessary.

#### Manufacture

502 All castings are to be made at foundries approved by the Committee.

Steel is to be manufactured in accordance with P 102.

All flame cutting, scarfing or arc-air gouging to remove surplus metal is to be completed before the final heat treatment of the casting and preheating is to be applied where necessary. The affected parts are to be ground smooth.

#### Chemical Composition

503 Castings are to be made in carbon or carbon-manganese steel. The chemical composition of ladle samples is to comply with the following:—

Carbon	... 0,23% max.
Silicon...	... 0,60% max.
Manganese	... 1,60% max. but not less than 3 times the actual carbon content.
Sulphur	... 0,050% max.
Phosphorus	... 0,050% max.
Residual elements, nickel, chromium, molybdenum, copper:—	total not to exceed 0,8%.

#### Heat Treatment

504 Steel castings are to be heat treated by any of the following methods:—

(1) Full annealing by heating to a temperature within the range 850°C to 950°C followed by cooling slowly in the furnace in a uniform manner.

(2) Normalizing by heating to a temperature within the range 850°C to 950°C followed by cooling in air and, where appropriate, subsequently tempering at a temperature of not less than 620°C.

(3) A combination of both of these treatments, e.g. annealing or homogenizing at a relatively higher temperature as a preliminary refining treatment to subsequent normalizing and tempering as in (2).

Heat treatment is to be carried out in properly constructed furnaces which are efficiently maintained and have adequate means for temperature control and are fitted with pyrometers which measure the temperature of the furnace charge. The furnace dimensions must permit the whole item being uniformly heated to the necessary temperature.

#### Test Material

505 (a) Test material for the preparation of at least one tensile and one bend test piece is to be cast attached to each casting at positions agreed between the manufacturer and Surveyor. When larger castings are made from more than one cast of steel, or are of complex design, the number of tests is to be agreed with the Surveyor.

The test material is not to be cut from the castings until heat treatment has been completed nor until the test material has been stamped by the Surveyor.

(b) The tensile test piece is to be machined to a diameter of 14 mm with a gauge length of 70 mm. Alternatively, at the request of the manufacturer, test pieces with other gauge lengths or larger diameters may be used.

(c) Bend test pieces are to be machined to either a rectangular section 25 mm wide by 20 mm thick or a round section 25 mm diameter. The sharp edges of rectangular section test pieces may be removed by suitable mechanical means to a radius not exceeding 1,5 mm.

#### Mechanical Properties

506 (a) All tests are to be carried out in the presence of the Surveyor.

(b) The tensile strength is to be between the limits of 400 and 540 N/mm<sup>2</sup>.

Elongation values are to be reported on a gauge length equal to  $5,65\sqrt{S_0}$ , where  $S_0$  is the cross-sectional area of the test piece. The elongation is to be not less than 20% and where the actual gauge length used is other than  $5,65\sqrt{S_0}$  the equivalent elongation is to be calculated using the formula or factors given in P 106 (b) (ii) or Q 202.



The bend test piece is to withstand being bent through an angle of 120° round a former having a diameter not greater than 60 mm.

(c) If for any reason after testing as above, a casting is given a further full annealing or normalizing heat treatment, e.g. after weld repairs, then the original tests are to be disregarded and further complete mechanical tests are to be made.

(d) Where either the tensile test or the bend test, or both, fail to meet the specified requirements, and the Surveyor considers the fractured test piece or test pieces, or the results obtained therefrom, do not fairly represent the quality of the casting, two further test pieces of the same type are to be taken for each original test that failed. In such cases the quality of the casting is to be judged by the result of the re-tests and not by the original test or tests which failed.

When one or both of the re-tests fail then the casting is to be rejected.

(e) At the option of the manufacturer, when tests on a casting fail to meet the specified requirements, the casting may be re-heat treated and re-submitted for test provided it is not heated above the upper critical temperature more than three times, i.e. original and two re-treatments.

### Inspection

**507** (a) The manufacturer is to make any tests necessary to prove the casting technique for prototype castings.

When castings are produced in regular quantities the manufacturer is to make periodical examinations to verify the continued efficiency of the manufacturing technique and the Surveyor is to be given the opportunity to witness these tests.

(b) All castings are to be cleaned and adequately prepared for inspection. Suitable methods include pickling, caustic cleaning, wire brushing, local grinding, shot or sand blasting. Before examination the surfaces must not be hammered, peened or treated in any way which may obscure defects.

(c) All important castings are to be examined by magnetic particle methods in at least all areas containing changes of section and where surplus metal has been removed by flame cutting, scarfing or arc-air gouging. The techniques employed are to be in accordance with recognized good practice, including any necessary surface preparation and are to be carried out by competent personnel

using reliable and efficiently maintained equipment. The term "magnetic particle examination" is intended to imply inspection for surface flaws using suitable magnetic methods but when this is not practicable a suitable dye penetrant method may be used instead.

(d) In all cases, in order to determine the soundness of the castings, supplementary examinations by radiography, ultrasonic, or other approved methods of non-destructive testing may be requested. When such examination is to be carried out it should be at positions, mutually agreed by the Surveyor and manufacturer, where experience shows that cavities, contraction cracks, or other defects are most likely to occur.

(e) The Surveyor is to examine each large casting before final acceptance at the foundry.

### Repair of Defects

**508** (a) When defects are found in a casting these are to be removed by grinding or by chipping and grinding. Flame scarfing or arc-air gouging may also be used provided that preheating is employed when necessary and that the surfaces of the resulting depressions are subsequently ground smooth. Complete elimination of the defective material is to be proved by magnetic particle tests. Shallow grooves or depressions resulting from the removal of defects can, at the Surveyor's discretion, be accepted provided these are blended by grinding.

(b) Proposals to repair a defective casting by welding are to be submitted to the Surveyor before work is commenced. The Surveyor is to satisfy himself that the number and size of the defects are such that the casting can be efficiently repaired.

When it has been agreed that the casting can be repaired, it is to be proved by suitable methods of inspection that the defects have been completely removed and the defective area is to be prepared in a form suitable for welding. All castings in alloy steels and, if necessitated by the shape, castings in carbon or carbon manganese steels are to be given a preliminary refining heat treatment prior to carrying out weld repairs. Such castings are also to be preheated to a suitable temperature. An electric arc welding process is to be used and the weld deposit is to have properties similar to and in no way inferior to the parent metal. Welding of the affected parts is to be undertaken by a procedure the essential elements of which have been tested previously by the manufacturers and approved by the Surveyor. The welding is to be done under cover in positions free from draughts and adverse weather conditions by competent welders with adequate supervision.



After welding, the castings are to be suitably heat treated either by annealing, normalizing and tempering or stress relieving at a temperature of not less than 600°C. The type of heat treatment employed will be dependent on the size, position and nature of the defects. On completion of heat treatment, the weld repairs and adjacent metal are to be ground smooth and proved by a suitable method of magnetic particle inspection. Subject to the approval of the Surveyor, a local stress relieving heat treatment may be carried out where the area involved is small and machining of the casting has reached an advanced stage.

### Identification

509 Before any casting is finally accepted it is to be clearly marked by the manufacturer in at least one place with the following particulars:—

- (a) "L.R." or "Lloyd's" and the abbreviated name of the Society's local office.
- (b) Identification mark which will enable the full history of the casting to be traced.
- (c) Date of final inspection.
- (d) Personal stamp of Surveyor responsible for final inspection.

### Documentation

510 The manufacturer is to supply the Surveyor with a written statement giving the steelmaking process, cast number, cast analysis, mechanical test results and general details of heat treatment together with full particulars of the purchaser, order number and description.

When repairs have been made by welding the manufacturer may be requested to provide the Surveyor with a statement and/or sketch detailing the extent and location of the repairs together with details of the heat treatment carried out at all stages.

## Section 6

### STEEL FORGINGS

#### Scope

601 Forgings for sternframes, rudder frames, rudder stocks, propeller shaft brackets and other steel forgings intended for use in hull construction are to be manufactured and tested in accordance with the requirements of this Section. These requirements are also applicable to rolled slabs or billets used as a substitute for forgings.

Where it is proposed to use low alloy steel forgings, particulars of the chemical composition, mechanical properties and heat treatment are to be submitted for

approval. These forgings are to be tested and accepted on the basis of the approved specification and such other tests as may be considered necessary.

### Manufacture

602 (a) The steel is to be manufactured in accordance with P 102.

When forgings are made from ingots, or from blooms forged from ingots, the ingots are to be cast in metal moulds with the larger cross-section uppermost and with efficient feeder heads. The forgings are to be gradually and uniformly hot worked and are to be brought as nearly as possible to the finished shape and size. Where practicable they are to be worked so as to cause metal flow in the most favourable direction having regard to the mode of stressing in service. Adequate top and bottom discards are to be made to ensure freedom from piping and harmful segregations in the finished forgings.

Unless otherwise approved the maximum sectional area of any part of a forging (as forged) is not to exceed:—

$\frac{1}{3}A$  where the length of any section is greater than its diameter,

$\frac{2}{3}A$  where the length of any section is less than its diameter (e.g. a collar).

$A$  is the average cross-sectional area of the ingot or of the ingot after upsetting if such an operation is involved.

(b) When forgings are made from rolled products the maximum sectional area of a forging (as forged) is not to exceed:—

(i) when made from products rolled from ingots cast large end uppermost with efficient feeder heads,  
 $\frac{1}{4}A$  where the length of any section is greater than its diameter,

or  $\frac{1}{2}A$  where the length of any section is less than its diameter (e.g. a collar),

or (ii) when made from products rolled from other types of ingots,

$\frac{1}{6}A$  where the length of any section is greater than its diameter,

or  $\frac{1}{3}A$  where the length of any section is less than its diameter (e.g. a collar),

$A$  is the average cross-sectional area of the original ingot.

(c) The shaping of forgings or rolled products by flame cutting is to be undertaken in accordance with a procedure approved by the Surveyor. Preheating is to be employed when necessitated by the thickness and on completion of



shaping the forgings or rolled products may require to be heat treated in accordance with 604 (b).

### Chemical Composition

603 (a) Forgings to which structural items are to be attached by welding or which are intended for parts of a fabricated component are to be made in carbon or carbon-manganese steel. The chemical composition of ladle samples is to comply with the following:—

Carbon	... 0,23% max.
Silicon...	... 0,15–0,50%
Manganese	... 0,30–1,60% but not less than 3 times the actual carbon content for components which are not given a post-weld heat treatment.
Sulphur	... 0,050% max.
Phosphorus	... 0,050% max.
Residual elements, nickel, chromium, molybdenum, copper:—	total not to exceed 0,8%.

(b) For forgings not intended for welding the chemical composition of ladle samples is to comply with the following:—

Carbon	... 0,30% max.
Silicon...	... 0,15–0,50%
Manganese	... 0,30–1,60%
Sulphur	... 0,050% max.
Phosphorus	... 0,050% max.
Residual elements, nickel, chromium, molybdenum, copper:—	total not to exceed 0,8%.

(c) Rolled products and forgings made from rolled products may have a silicon content of less than 0,15% i.e. semi-killed steel, provided that the cross-sectional area does not exceed 195 cm<sup>2</sup>.

### Heat Treatment

604 (a) All forgings and rolled products intended as a substitute for forgings are to be heat treated by any of the following methods:—

(1) Full annealing by heating to a temperature within the range 850°C to 950°C followed by cooling slowly in the furnace in a uniform manner, or

(2) normalizing by heating to a temperature within the range 850°C to 950°C followed by cooling in air and subsequently tempering at a temperature of not less than 580°C if the diameter of the body of the forging is equal to or greater than 900 mm. Smaller diameter forgings may also be tempered after the normalizing heat treatment at the option of the forgemaster.

(b) If flame cutting or shaping is carried out subsequent to the above heat treatment, a further normalizing or a stress relieving heat treatment may be required, depending on the extent of flame cutting and whether sufficient material is subsequently to be machined from the flame cut surfaces.

When a stress relieving heat treatment is required, this is to be carried out in the temperature range of 600°C to 650°C.

(c) Heat treatment is to be carried out in properly constructed furnaces which are efficiently maintained and have adequate means for temperature control and are fitted with pyrometers which measure the temperature of the furnace charge. The furnace dimensions must permit the whole item being uniformly heated to the necessary temperature.

(d) Rolled products intended for forging stock and subsequent hot working do not require to be supplied in the heat treated condition.

### Test Material

605 (a) Test material is to be provided integral with the forging and with a cross-sectional area of not less than that of the main part of the forging. At least one tensile and one bend test are to be taken from each forging, except where both the weight and length are in excess of 4 tonnes and 3 m respectively, when tensile and bend tests are to be taken from each end. These limits refer to the "as forged" weight and length but excluding the test material.

(b) When a forging is subsequently divided into a number of items all of which are heat treated together in the same furnace then for test purposes this may be considered as one forging and the test material required is to be related to the total length and weight of the original forging.

Where a number of separate forgings are made from one cast of steel and are heat treated together in one furnace then a system of batch testing may be adopted. The number of tests required and the method of providing the test material is to be agreed with the Surveyor.

(c) For rolled products at least one tensile and one bend test piece are to be taken from each piece (see P 105 (e)) except where these are intended for forging stock and will subsequently be hot worked.

(d) Tensile and bend test pieces are to be cut longitudinally or parallel to the direction of principal grain flow. Where test pieces cannot reasonably be provided in the longitudinal direction they may be cut in a transverse



direction. The test material is not to be cut from the forgings until heat treatment has been completed nor until the test material has been stamped by the Surveyor.

(e) The tensile test piece is to be machined to a diameter of 14 mm with a gauge length of 70 mm. Alternatively, at the request of the manufacturer, test pieces with other gauge lengths or larger diameters may be used.

Bend tests are to be machined to a rectangular section 25 mm wide and 20 mm thick. The sharp edges of the test pieces may be removed by suitable mechanical means to a radius not exceeding 1,5 mm.

### Mechanical Properties

606 (a) All tests are to be carried out in the presence of the Surveyor.

(b) The tensile strength is to be between the limits of 430 and 530 N/mm<sup>2</sup>.

Elongation values are to be reported on a gauge length equal to  $5,65\sqrt{S_0}$ , where  $S_0$  is the cross-sectional area of the test piece. The elongation is to be not less than 22% for tests in the longitudinal direction and not less than 18% for tests in the transverse direction. Where the actual gauge length used is other than  $5,65\sqrt{S_0}$  the equivalent elongation is to be calculated using the formula or factors given in P 106 (b) (ii) or Q 202.

Bend test pieces which are cut in a longitudinal direction are to withstand being bent without fracture through an angle of 180° round a former having a diameter not greater than 12,5 mm. For test pieces cut in a transverse direction the diameter of the former is to be not greater than 25 mm.

(c) Where either the tensile test or the bend test, or both, fail, and the Surveyor considers the fractured test piece or test pieces, or the results obtained therefrom, do not fairly represent the quality of the forging then the procedure given in P 506 (d) or (e) may be adopted.

### Inspection

607 The Surveyor is to examine each forging before final acceptance at the forge.

### Repair of Defects

608 (a) When defects are found in a forging these are to be removed by grinding or by chipping and grinding. Complete elimination of the defective material is to be proved by magnetic particle tests. Shallow grooves or depressions resulting from the removal of defects can be accepted at the Surveyor's discretion provided they are blended by grinding.

(b) Repair by welding is not generally permitted, but special consideration will be given to such repairs when they are of a minor nature and in areas of low working stresses. Proposals are to be submitted to the Surveyor before work is commenced and the Surveyor is to satisfy himself that the number and size of the defects are such that the forgings can be efficiently repaired.

(c) When it has been agreed that the forging can be repaired it is to be proved by suitable methods of inspection that the defects have been completely removed and the defective area is to be prepared in a form suitable for welding. An electric arc welding process is to be used and the weld deposit is to have properties similar to and in no way inferior to the parent metal. Welding of the affected parts is to be undertaken by a procedure the essential elements of which have been tested previously by the manufacturer and approved by the Surveyor. The welding is to be done under cover in positions free from draughts and adverse weather conditions by competent welders with adequate supervision.

After welding, the forgings are to be suitably heat treated either by annealing, normalizing and tempering or stress relieving at a temperature of not less than 600°C. The type of heat treatment employed will be dependent on the size, position and nature of the defects. On completion of heat treatment, the weld repairs and adjacent metal are to be ground smooth and proved by a suitable method of magnetic particle inspection.

### Identification

609 Forgings are to be identified in the same manner as for steel castings, *see* P 509.

### Documentation

610 The manufacturer is to supply the information required as for steel castings, *see* P 510.

When repairs have been made by weldings the manufacturer is to provide a written statement and/or sketch detailing the extent and location of the repairs together with details of the heat treatment carried out at all stages.

## Section 7

### STEEL ANCHORS

#### Process of Manufacture

701 Forged steel anchor heads and shanks are to be manufactured and tested in accordance with the relevant requirements of P 6 except that heat treatment need only be carried out when the weight of the forging exceeds 3 tonnes.



Cast steel anchor heads and shanks are to be manufactured and tested in accordance with the relevant requirements of P 5 except that where more than one anchor casting is made from the same cast, only one tensile and one bend test piece need be taken provided all the castings are heat treated in the same batch and that the weight of the cast is 3 tonnes or less. Additional tests are to be taken when the cast is in excess of this weight.

**702** Each important part of an anchor is to be plainly marked by the maker with the words "forged ingot steel" or "heat treated cast steel" as the case may be (or simply "forged steel" or "cast steel").

**703** Steel anchor shackles are to be made of forged steel or cast steel as specified in 701, but need not be submitted to the test requirements of P 5 and P 6.

#### Proof Tests of Anchors

**704** Anchors weighing more than 76 kg inclusive of stock, are to be tested at a proving establishment recognized by the Committee (*see* D 3421). When the (United Kingdom) Anchors and Chain Cables Act applies\* the anchors are to be tested at a certified testing establishment.

\*NOTE. The Anchors and Chain Cables Act 1967, applies to anchors used on ships registered in the United Kingdom.

**705** The proof test load is to be as given in Table P 7.1. The weight to be used in the Table is:—

- (a) for stockless anchors—the total weight of the anchor,
- (b) for stocked anchors—the weight of the anchor excluding the stock,
- (c) for high holding power anchors (*see* 706)—a nominal weight equal to 1.33 times the actual total weight of the anchor.
- (d) for mooring anchors (*see* 708) a nominal weight equal to 1.33 times the actual total weight of the anchor, unless specifically agreed otherwise.

#### High Holding Power Anchors

**706** Anchors of designs for which approval is sought as "High Holding Power" anchors are to be tested at sea to show that they have holding powers of at least twice those of "Admiralty Standard Stockless" anchors of the same weight.

If approval is sought for a range of sizes then at least two sizes are to be tested. The smaller of the two anchors is to have a weight not less than  $\frac{1}{10}$  of that of the larger anchor, and the larger of the two anchors tested is to have a weight not less than  $\frac{1}{10}$  of that of the largest anchor for which approval is sought.

The tests are to be conducted on not less than 3 different types of bottom which should normally be soft mud or silt, sand or gravel, and hard clay or similarly compacted material.

The test should normally be carried out from a tug and the pull measured by dynamometer or derived from recently verified curves of tug rpm/bollard pull. A scope of 10 is recommended for the anchor cable, which may be wire rope for this test, but in no case should a scope of less than 6 be used. The same scope is to be used for the anchor for which approval is sought and the anchor that is being used for comparison purposes.

**707** High holding power anchors are to be of a design that will ensure that the anchor will take effective hold of the sea bed without undue delay and will remain stable, for holding forces up to those required by 706, irrespective of the angle or position at which they first settle on the sea bed when dropped from a normal type of hawse pipe. In case of doubt a demonstration of these abilities may be required.

#### Mooring Anchors

**708** Anchors which must be specially laid the right way up or which require the fluke angle or profile to be adjusted for varying types of sea bed will not generally be approved for normal ship use but may be accepted for Offshore Units, Floating Cranes, etc. In such cases suitable tests may be required.



TABLE P 7.1 PROOF TESTS FOR ANCHORS

WEIGHT OF ANCHOR (see P 705)	PROOF TEST LOAD	WEIGHT OF ANCHOR (see P 705)	PROOF TEST LOAD	WEIGHT OF ANCHOR (see P 705)	PROOF TEST LOAD	WEIGHT OF ANCHOR (see P 705)	PROOF TEST LOAD	WEIGHT OF ANCHOR (see P 705)	PROOF TEST LOAD	WEIGHT OF ANCHOR (see P 705)	PROOF TEST LOAD
kg	kN	kg	kN	kg	kN	kg	kN	kg	kN	kg	kN
50	23,2	550	125,0	2200	376,0	4800	645,0	7800	861,0	17 500	1390,0
55	25,2	600	132,0	2300	383,0	4900	653,0	8000	877,0	18 000	1410,0
60	27,1	650	140,0	2400	401,0	5000	661,0	8200	892,0	18 500	1440,0
65	28,9	700	149,0	2500	414,0	5100	669,0	8400	908,0	19 000	1470,0
70	30,7	750	158,0	2600	427,0	5200	677,0	8600	922,0	19 500	1490,0
75	32,4	800	166,0	2700	438,0	5300	685,0	8800	936,0	20 000	1520,0
80	33,9	850	175,0	2800	450,0	5400	691,0	9000	949,0	21 000	1570,0
90	36,3	900	182,0	2900	462,0	5500	699,0	9200	961,0	22 000	1620,0
100	39,1	950	191,0	3000	474,0	5600	706,0	9400	975,0	23 000	1670,0
120	44,3	1000	199,0	3100	484,0	5700	713,0	9600	987,0	24 000	1720,0
140	49,0	1050	208,0	3200	495,0	5800	721,0	9800	998,0	25 000	1770,0
160	53,2	1100	216,0	3300	506,0	5900	728,0	10 000	1010,0	26 000	1800,0
180	57,4	1150	224,0	3400	517,0	6000	735,0	10 500	1040,0	27 000	1850,0
200	61,3	1200	231,0	3500	528,0	6100	740,0	11 000	1070,0	28 000	1900,0
225	65,8	1250	239,0	3600	537,0	6200	747,0	11 500	1090,0	29 000	1940,0
250	70,4	1300	247,0	3700	547,0	6300	754,0	12 000	1110,0	30 000	1990,0
275	74,9	1350	255,0	3800	557,0	6400	760,0	12 500	1130,0	31 000	2030,0
300	79,5	1400	262,0	3900	567,0	6500	767,0	13 000	1160,0	32 000	2070,0
325	84,1	1450	270,0	4000	577,0	6600	773,0	13 500	1180,0	34 000	2160,0
350	88,8	1500	278,0	4100	586,0	6700	779,0	14 000	1210,0	36 000	2250,0
375	93,4	1600	292,0	4200	595,0	6800	786,0	14 500	1230,0	38 000	2330,0
400	97,9	1700	307,0	4300	604,0	6900	794,0	15 000	1260,0	40 000	2410,0
425	103,0	1800	321,0	4400	613,0	7000	804,0	15 500	1270,0	42 000	2490,0
450	107,0	1900	335,0	4500	622,0	7200	818,0	16 000	1300,0	44 000	2570,0
475	112,0	2000	349,0	4600	631,0	7400	832,0	16 500	1330,0	46 000	2650,0
500	116,0	2100	362,0	4700	638,0	7600	845,0	17 000	1360,0	48 000	2730,0

## NOTES

1. Proof loads for intermediate weights are to be determined by linear interpolation.
2. Where anchors exceeding the Table value of weights are to be tested, the proof loads are to be taken as:—
  - for ordinary anchors  $2,059 (\text{anchor weight in kg})^{\frac{2}{3}} \text{ kN}$
  - for high holding power anchors  $2,452 (\text{anchor weight in kg})^{\frac{2}{3}} \text{ kN}$



**Section 8****STUD LINK AND SHORT LINK CHAINS**

*Note. For list of approved manufacturers of stud link chain cable see Appendix 2 following Chapter Q.*

**General**

**801** Stud link chain for anchor cable is to comply with 802 to 814 and may be of any grade shown in Table P 8.1.

Provision is made for the testing of bar material intended for the manufacture of welded stud link chain, material tests for drop forged and cast links and the testing of completed chain, attachment links and shackles.

Short link chain for anchor cable or steering chains is to comply with 815 to 818. For convenience the specified test loads are given in Table P 8.4.

**Method of Manufacture**

**802** The methods of manufacture of Grades 1(a) and 1(b) do not require to be approved but rimming steel should not be used.

**803** The steel used for the manufacture of Grades U 1, U 2 and U 3 chain cable is to be made in accordance with P 102. Rimming steel is not acceptable.

The links may be made by the flash-butt or other approved welding process or they may be steel castings or drop forgings. The method of manufacture and the chemical composition are to be approved and the requisite preliminary tests carried out. Approval tests for higher grades cover lower grades (up to the same diameter) provided the method of manufacture and heat treatment are generally the same.

**Chemical Composition**

**804** The chemical composition is to comply with the manufacturer's approved specification and is to be determined in accordance with P 103.

**Heat Treatment**

**805** (a) Bar material intended for the manufacture of chain may be supplied in the "as rolled" or heat treated condition in accordance with the requirements of the chain maker.

(b) **HEAT TREATMENT OF COMPLETED CHAIN.** Grade U 1 chain cable may either be supplied in the "as welded" condition or may be normalized. If supplied in the "as welded" condition additional breaking tests will be required as detailed in Table P 8.2.

Grade U 2(a) cable is to be normalized. Grade U 2(b) cast steel cable is to be normalized, or may, at option of the manufacturer, be hardened by quenching and tempered.

Grade U 3 cable is to be normalized, normalized and tempered, or hardened by quenching and tempered.

In all cases heat treatment is to be carried out prior to the proof loading and breaking tests of the completed chains and links.

**806** For certain types of drop forged cable the requirements of 805, and the procedure for material tests, will be specially considered.

**Test Material and Test Pieces**

**807** (a) For Grades U 1 and U 2(a) the bar material may be tested either in the "as rolled" condition or after heat treatment in full size and in a manner simulating the heat treatment applied to the finished cable. For Grade U 3(a) the test material is to be heat treated in full size and in a manner simulating the treatment applied to the finished chain.

Test material representative of cast or drop forged links is to be heat treated along with and in the same manner as the completed cable (*see also* 806).

(b) For all grades of chain cable, tests are to be carried out to establish that the material complies with the requirements of Table P 8.1. For bar material intended for the manufacture of fire welded or flash-butt welded cable and for drop-forgings, one set of tests is to be carried out on a sample of the largest diameter bar (forging) in each batch of 40 tonnes (tons) or fraction thereof from the same cast. For cast steel cable, the sets of tests are to be carried out on separately cast test blocks representative of each of the casts used to manufacture the cable.

From completed chain, 3-link samples are to be selected by the Surveyor for the breaking tests specified in 810(b). In addition, for Grade U 3, extra links are required for the mechanical tests specified in 811(c).

(c) Tensile test pieces may be either the full section "as rolled" or of the round proportional type provided the cross-sectional area is not less than 160 mm, and the machining is in accordance with a recognized National Standard. For machined test pieces the diameter of the reduced portion and the position of the test piece relative to the bar cross-section are to be selected so that the test piece is representative of the average properties of the bar.

For cast or drop forged links test pieces of the machined type are to be used.

The gauge length is generally to be five times the diameter of the test portion. For other gauge lengths the



equivalent elongations are to be determined in accordance with P 106(b) (ii). For Grade U 3(a) cable the minimum reduction of area = 40 per cent, and for Grade U 3(b) = 35 per cent.

Bend test pieces may be either the full section as rolled, or may be machined to 25 mm diameter, or rectangular cross-section 25 × 19 mm.

Impact test pieces are to be of the Charpy V-notch type in accordance with P 105(d). They are to be cut as shown in Fig. P 8.1:—

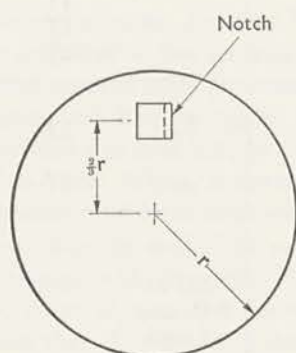


FIG. P 8.1

(d) Additional tests before rejection may be taken in accordance with P 106(d).

#### Mechanical Properties

808 In all cases the results of tensile bend and impact tests are to comply with Table P 8.1.

#### STUD LINK CHAIN

##### Dimensional Tolerances

809 Manufacturing tolerances on new stud link chain are to be within  $\pm 2\frac{1}{2}$  per cent (taking into account that all components of the chain are to be a good fit with one another) except for the following negative tolerances:—

Cross-sectional area at crown:— —nil

Diameter at crown measured in the plane of the link:—

—1 mm when  $d_c \leq 40$  mm

—2 mm when  $40 \text{ mm} < d_c < 84$  mm

—3 mm when  $d_c \geq 84$  mm

Length over five links:— —nil

For permitted wear down on used cables, see C 219.

#### Inspection and Testing of Completed Chain

810 All chain cable is to be tested in the presence of a Surveyor, at a proving establishment recognized by the Committee (see D 3420 and Appendix 2 following Chapter Q). When the (United Kingdom) Anchors and Chain Cables Act\* applies the cables are to be tested at a certified testing establishment.

\*NOTE. The Anchors and Chain Cables Act 1967, applies to chain cables used on ships registered in the United Kingdom.

The tests detailed in 811 are to be applied.

Each length of chain is to be carefully examined after proof loading and is to be free from significant defects.

811 (a) **PROOF LOADING TEST.** Each length of chain cable is to be subjected to a proof loading test in an approved testing machine and is to withstand the load given in Table P 8.3 for the appropriate grade and size of cable.

(b) **BREAKING TEST.** Breaking test specimens are to be taken as required by Table P 8.2 and are to withstand the load given in Table P 8.3 for the appropriate grade and size of cable. The specimen shall be considered to have passed this test if it has shown no sign of fracture after application of the required load.

Where a breaking test specimen fails, a further specimen is to be cut from the same length of cable and subjected to test. If this re-test fails, the length of cable from which it was taken is to be rejected. When this test is also representative of other lengths, each of the remaining lengths is to be individually tested by taking a breaking test specimen from each length of the batch.

For large diameter cables where the required breaking load is greater than the capacity of the testing machines, special consideration will be given to acceptance of an alternative testing procedure.

(c) **MECHANICAL TESTS.** For Grade U 3 chain cable, 1 tensile and 2 sets of 3 impact test pieces are to be taken from every four or less 27.5 m lengths of cable.

The test pieces for the tensile and 1 set of the impact test pieces are to be taken clear of the weld, the remaining impact test pieces are to have the notch positioned at the weld centre.

Test pieces are not to be selected from the same length as that from which the breaking test sample has been taken unless breaking test samples have been taken from every length of the batch.

The results of these tests are to comply with the requirements given in Table P 8.1.

TABLE P 8.1

DESIGNATION	METHOD OF MANUFACTURE	TENSILE STRENGTH N/mm <sup>2</sup>	ELONGATION (on 5D) MINIMUM %	IMPACT MINIMUM	MAXIMUM DIAMETER OF FORMER
Wrought Iron Grade 1(a)	Fire welded	300-400	30	—	1T
Mild Steel Grade (b)	Fire welded	300-400	30	—	1T
U 1(a)	Flash-butt welded	300-400	30	—	1T
U 1(b)	" " "	400-490	25	—	2T
Special Quality Grade U 2(a)	Flash-butt welded or drop forged	490-640	22	—	3T
U 2(b)	Cast Steel	490 min.	22	—	3T
Extra Special Quality Grade U 3(a)	Flash-butt welded or drop forged	690 min.	17	*59J at 0°C clear of weld *49J at 0°C in way of weld	— —
U 3(b)	Cast Steel	690 min.	17	*59J at 0°C	—

- NOTES. 1. T is equal to the diameter or thickness of the bend test piece.  
 2. For Grade U 3 cable, minimum reduction of area, *see* 807 (c).  
 3. Except where otherwise stated Grades 1(a) and 1(b) are to comply with all the requirements for Grade U 1(a) not heat treated.  
 \* Average value from 3 test specimens.

TABLE P 8.2 NUMBER OF BREAKING TESTS

DESIGNATION	METHOD OF MANUFACTURE	NUMBER OF BREAKING TEST SPECIMENS
Grade 1(a) 1(b)	Fire welded	One from each length of 27,5 m or less
Grade U 1 U 2(a) U 3(a)	Flash-butt welded, or drop forged, and heat treated	One from every four lengths of 27,5 m or less
Grade U 1	Flash-butt welded but not heat treated	One from each length of 27,5m or less
Grade U 2(b) U 3(b)	Cast and heat treated	One per heat treatment batch with a mini- mum of one from every four lengths of 27,5 m or less



**812 SHACKLES.** End and joining shackles are to be subjected to the breaking and proof loads appropriate to the grade of cable for which they are intended. The breaking load shall be applied to at least 1 shackle out of 25 (1 in 50 for lugless shackles) and this item is to be destroyed and not used as part of an outfit.

Drop forged, cast steel and lugless shackles are to be manufactured to an agreed specification and tensile and impact or bend tests taken. The test samples are to be subjected to the same heat treatment as the shackles.

**813 ATTACHMENT LINKS, ADAPTOR PIECES, SWIVELS, ETC.,** are to be subjected to the breaking and proof loads appropriate to the grade of cable for which they are intended. The breaking load is to be applied to 1 item out of every 25 (or less) and this item is to be destroyed and not used as part of an outfit. Where, however, the items are of increased dimensions, and have been specially approved, the breaking load may be applied to each item and the item so tested included with the outfit. For the purpose of this paragraph, items of increased dimensions are those items so designed that their breaking strength is not less than 1.4 times the Rule minimum breaking strength of the chain cable with which they are to be used.

**814** All items subjected to the breaking load are to be destroyed and not used in the outfit except as specifically permitted by 813 for items of increased dimensions.

## SHORT LINK CHAIN

### Dimensions and Characteristics

**815** Short link chain is, in general, to comply with the requirements of the International Standards Organization standards ISO/R 1834—1971, R 1835—1971 and

R 1836—1971 as appropriate. No objection will be raised to short link chain being galvanized, provided the proof test requirements are achieved after galvanizing is completed. Consideration will be given to relaxations of dimensional tolerances of galvanized chain derived from R 1836—1971 to allow for the effect of galvanizing.

### Inspection and Testing

**816** All chain cables of 12.5 mm and above in diameter, and steering chains, are to be tested at a proving establishment recognized by the Committee (*see* D 3420 and Appendix 2 following Chapter Q). When the (United Kingdom) Anchors and Chain Cables Act\* applies, the cables are to be tested at a certified testing establishment. The test loads for ISO Grade 40 chain are given in Table P 8.4.

\*NOTE. The Anchors and Chain Cables Act 1967, applies to chain cables of 12.5 mm and above, in diameter, used on ships (including yachts) registered in the United Kingdom.

Each length of chain is to be carefully examined after proof loading and is to be free from significant defects.

### Documentation

**817** The manufacturer is to supply the Surveyor with a certificate stating compliance with ISO/R 1834—1971, R 1835—1971 and/or R 1836—1971 as applicable, and also, in the event of the requirements of 816 being undertaken other than in the presence of the Surveyor, stating that the test and inspection requirements have been complied with at a recognized proving establishment.

The name of the proving establishment is to be included on the certificate. For a list of recognized Proving Establishments, *see* Appendix 2 following Chapter Q.

**818** For permitted wear-down on used chain, *see* C 103 and C 219.

TABLE P 8.3 STUD LINK CHAIN CABLE

CHAIN DIAMETER	GRADE					
	U 1		U 2		U 3	
	Proof Load	Breaking Load	Proof Load	Breaking Load	Proof Load	Breaking Load
mm	kN	kN	kN	kN	kN	kN
12,5	46,1	65,7	65,7	92,2	92,2	132,0
14	57,9	82,4	82,4	116,0	116,0	165,0
16	75,5	107,0	107,0	150,0	150,0	216,0
17,5	89,2	127,0	127,0	179,0	179,0	256,0
19	105,0	150,0	150,0	211,0	211,0	301,0
20,5	123,0	175,0	175,0	244,0	244,0	349,0
22	140,0	200,0	200,0	280,0	280,0	401,0
24	167,0	237,0	237,0	332,0	332,0	476,0
26	194,0	278,0	278,0	389,0	389,0	556,0
28	225,0	321,0	321,0	449,0	449,0	642,0
30	257,0	368,0	368,0	514,0	514,0	735,0
32	291,0	417,0	417,0	583,0	583,0	833,0
34	328,0	468,0	468,0	655,0	655,0	937,0
36	366,0	523,0	523,0	732,0	732,0	1050,0
38	406,0	581,0	581,0	812,0	812,0	1160,0
40	448,0	640,0	640,0	896,0	896,0	1280,0
42	492,0	703,0	703,0	981,0	981,0	1400,0
44	538,0	769,0	769,0	1080,0	1080,0	1540,0
46	585,0	837,0	837,0	1170,0	1170,0	1680,0
48	635,0	908,0	908,0	1270,0	1270,0	1810,0
50	686,0	981,0	981,0	1370,0	1370,0	1960,0
52	739,0	1060,0	1060,0	1480,0	1480,0	2110,0
54	794,0	1140,0	1140,0	1590,0	1590,0	2270,0
56	851,0	1220,0	1220,0	1710,0	1710,0	2430,0
58	909,0	1290,0	1290,0	1810,0	1810,0	2600,0
60	969,0	1380,0	1380,0	1940,0	1940,0	2770,0
62	1030,0	1470,0	1470,0	2060,0	2060,0	2940,0
64	1100,0	1560,0	1560,0	2190,0	2190,0	3130,0
66	1160,0	1660,0	1660,0	2310,0	2310,0	3300,0
68	1230,0	1750,0	1750,0	2450,0	2450,0	3500,0
70	1290,0	1840,0	1840,0	2580,0	2580,0	3690,0
73	1390,0	1990,0	1990,0	2790,0	2790,0	3990,0
76	1500,0	2150,0	2150,0	3010,0	3010,0	4300,0
78	1580,0	2260,0	2260,0	3160,0	3160,0	4500,0
81	1690,0	2410,0	2410,0	3380,0	3380,0	4820,0
84	1800,0	2580,0	2580,0	3610,0	3610,0	5160,0
87	1920,0	2750,0	2750,0	3850,0	3850,0	5500,0
90	2050,0	2920,0	2920,0	4090,0	4090,0	5840,0
92	2130,0	3040,0	3040,0	4260,0	4260,0	6080,0
95	2260,0	3230,0	3230,0	4510,0	4510,0	6440,0
97	2340,0	3340,0	3340,0	4680,0	4680,0	6690,0
100	2470,0	3530,0	3530,0	4940,0	4940,0	7060,0
102	2560,0	3660,0	3660,0	5120,0	5120,0	7320,0
105	2700,0	3850,0	3850,0	5390,0	5390,0	7700,0
107	2790,0	3980,0	3980,0	5570,0	5570,0	7960,0
111	2970,0	4250,0	4250,0	5940,0	5940,0	8480,0
114	3110,0	4440,0	4440,0	6230,0	6230,0	8890,0
117	3260,0	4650,0	4650,0	6510,0	6510,0	9300,0
120	3400,0	4850,0	4850,0	6810,0	6810,0	9720,0
122	3500,0	5000,0	5000,0	7000,0	7000,0	9990,0
124	3600,0	5140,0	5140,0	7200,0	7200,0	10 280,0
127	3750,0	5350,0	5350,0	7490,0	7490,0	10 710,0
130	3900,0	5570,0	5570,0	7800,0	7800,0	11 140,0
132	4000,0	5720,0	5720,0	8000,0	8000,0	11 420,0
137	4260,0	6080,0	6080,0	8510,0	8510,0	12 160,0
142	4520,0	6450,0	6450,0	9030,0	9030,0	12 910,0
147	4790,0	6840,0	6840,0	9560,0	9560,0	13 660,0
152	5050,0	7220,0	7220,0	10 100,0	10 100,0	14 430,0
157	5320,0	7600,0	7600,0	10 640,0	10 640,0	15 200,0
162	5590,0	7990,0	7990,0	11 180,0	11 180,0	15 980,0

Table P 8.3



TABLE P 8.4 TEST LOADS FOR ISO GRADE 40 CHAIN

NOMINAL DIAMETER $d_c$	PROOF LOAD	BREAKING LOAD	ENERGY ABSORPTION FACTOR *
mm	kN	kN	kJ/m
6,3	12,5	24,9	4,50
7,1	15,8	31,6	5,70
8	20,1	40,2	7,25
9	25,4	50,9	9,18
10	31,4	62,8	11,3
11,2	39,4	79,0	14,2
12,5	49,2	98,4	17,7
14	61,8	124	22,2
16	80,4	161	29,0
18	102	204	37,7
20	126	252	45,3
22,4	158	316	56,8
25	197	394	70,7
28	246	492	89,0
32	322	644	116
36	407	814	147
40	503	1010	181

\* Defined in ISO/R 1834—1971

## Section 9

### STEEL WIRE ROPES FOR STANDING RIGGING, TOWLINES AND MOORING LINES

*Note.* For list of manufacturers of steel wire ropes, see Appendix 2 following Chapter Q.

#### Approval of Works

901 The manufacturer's plant and method of production are to be approved by the Committee. The works are to be at all times open to inspection of the Surveyor and periodical inspections are to be held at intervals not exceeding 2 years.

Each manufacturer is required to provide on his premises machines suitable for satisfactorily making the prescribed tests. The tensile testing machine is to be of an approved type and is to be calibrated at intervals not exceeding 2 years. Alternatively, tests carried out by a competent government, municipal or similar responsible body will be accepted.

#### Material

902 The wire used in the manufacture of the rope is to be drawn from steel made by the open hearth, electric furnace or oxygen process, or by other process approved by the Committee, and is to be of homogeneous quality, consistent strength and free from visual defects likely to impair the performance of the rope. The tensile strength of the wire should generally be within the ranges 1420–1570 N/mm<sup>2</sup> (145–160 kgf/mm<sup>2</sup>), 1570–1770 N/mm<sup>2</sup> (160–180 kgf/mm<sup>2</sup>), or 1770–1960 N/mm<sup>2</sup> (180–200 kgf/mm<sup>2</sup>).

#### Galvanizing

903 The wire is to be galvanized by the hot dip or the electrolytic process to give a continuous uniform coating complying with the test requirements specified in 909 and 910. The coating may be any of the following grades:—

Grade 1—Heavy coating, drawn after galvanizing.

Grade 2—Heavy coating, finally galvanized.

Grade 3—Light coating, drawn after galvanizing.

#### Construction of Ropes

904 The construction of wire ropes for standing rigging, towlines and mooring lines is generally to be as given in Table P 9.1, but alternative types of wire rope will be specially considered on the basis of an equivalent breaking load and the suitability of the construction for the purpose intended.

#### Tests

905 A sample of the completed rope is to be subjected to a breaking test to destruction. The sample is to be of sufficient length to provide a clear test length of at least 36 times the rope diameter. Not more than four-fifths of the nominal breaking load may be applied quickly and thereafter the load is to be applied slowly and steadily until the maximum load is obtained.

Tests in which a breakage occurs adjacent to the grips may, at the option of the manufacturer, be neglected.

The actual breaking load is not to be less than that given in an appropriate National Standard.

906 If facilities are not available for making a breaking test on completed ropes intended for standing rigging or mooring lines, consideration will be given to the acceptance of the determination of the breaking load by the summation of the tests of individual wires and the deduction of a percentage for laying up. This percentage is not to be less than that given in Table P 9.2. Manufacturers desiring to adopt this method of testing may be required to arrange for check breaking tests to be carried out on completed ropes.

TABLE P 9.1

PURPOSE	CONSTRUCTION OF ROPE			CONSTRUCTION OF STRANDS
	Strands	Wires	Core	
Standing rigging	6	7	Fibre	6 over 1
	7	7	Wire	6 over 1
	7	19	Wire	12 over 6 over 1
	7	37	Wire	18 over 12 over 6 over 1
Recommended towlines and mooring lines	6	24	Fibre	15 over 9 over fibre core
	6	37	Fibre	18 over 12 over 6 over 1
	6	26	Fibre	10 over (5 + 5) over 5 over 1
	6	31	Fibre	12 over (6 + 6) over 6 over 1
	6	36	Fibre	14 over (7 + 7) over 7 over 1
	6	41	Fibre	16 over (8 + 8) over 8 over 1
	6	30	Fibre	18 over 12 over fibre core
	6	54	Fibre	24 over 18 over 12 over fibre core
	6	61	Fibre	24 over 18 over 12 over 6 over 1
Recommended towlines and mooring lines used in association with mooring winches	6	42	Fibre	6 × (6 over 1) over fibre core
	6	31	7 × 7 Wire Rope	12 over (6 + 6) over 6 over 1
	6	36	7 × 7 Wire Rope	14 over (7 + 7) over 7 over 1
	6	41	7 × 7 Wire Rope	16 over (8 + 8) over 8 over 1

NOTE. See Table SD 34.1, Notes 3 and 4, in the *Rules for Small Ships*.

TABLE P 9.2

CONSTRUCTION OF ROPE	PERCENTAGE DEDUCTION
6 × 7	10
6 × 24	13
6 × 37	17,5
7 × 7	15
7 × 19	18
7 × 37	22,5

NOTE. Percentage deductions for other constructions should either be in accordance with a recognized National Standard or are to be established by breaking tests carried out on completed ropes.

907 A suitable length is to be cut off the rope, unstranded and straightened, and six wires subjected to a torsion test (see 908) and six wires to a wrap test for adhesion of coating (see 910).

Alternatively, these tests may be carried out on the wire before the rope is stranded.

#### Torsion Test

908 The length of sample is to be such as to allow a distance between the grips of 100 times the diameter of wire, but this distance need not exceed 300 mm. The wire is to be twisted by causing one or both of the vices to be revolved until fracture occurs. The speed of testing should not exceed, for a length equal to 100 times the diameter, that given in Table P 9.3.

(A tensile load not exceeding 2 per cent of the breaking load of the wire may be applied to keep the wire stretched.)

TABLE P 9.3

DIAMETER OF COATED WIRE mm		MAXIMUM SPEED OF TESTING TWISTS PER MINUTE
From (Including)	Up to (Excluding)	
1,5	1,5	90
3,0	3,0	60
5,0	5,0	30



The wire is to withstand, on a length of 100 times the diameter of wire, the number of complete twists given in Table P 9.4.

### Weight and Uniformity of Zinc Coating

909 The weight of coating is to comply with the minimum figures shown in Table P 9.5 when tested in accordance with a recognized Standard.

The uniformity of the zinc coating is to be tested by a dip test, carried out in accordance with a recognized Standard.

### Wrap Test for Adhesion of Coating

910 The adhesion of the coating is to be tested by wrapping the wire round a cylindrical mandrel for ten complete turns of wrap. The ratio between the diameter of the mandrel and that of the wire is to be as in Table P 9.6.

After winding on the appropriate mandrel the zinc coating should neither have flaked nor cracked to such an extent that any zinc can be removed by rubbing with the bare fingers.

TABLE P 9.4

DIAMETER OF COATED WIRE mm		NUMBER OF TWISTS			
From (Including)	Up to (Excluding)	Grade 2		Grade 1 or 3	
		Tested Before Stranding	Tested After Stranding	Tested Before Stranding	Tested After Stranding
1,3	1,3	15	13	27	24
2,3	2,3	15	13	26	23
2,3	3,0	14	12	23	20
3,0	4,0	12	10	21	18

TABLE P 9.5

DIAMETER OF COATED WIRE mm		COATING	
From (Including)	Up to (Excluding)	Grade 1 or 2	Grade 3
		gm/m <sup>2</sup>	gm/m <sup>2</sup>
0,40	0,50	75	40
0,50	0,60	90	50
0,60	0,80	110	60
0,80	1,00	130	70
1,00	1,20	150	80
1,20	1,50	165	90
1,50	1,90	180	100
1,90	2,50	205	110
2,50	3,20	230	125
3,20	4,00	250	135

TABLE P 9.6

COATING	WIRE DIAMETER LESS THAN 1,5 mm	WIRE DIAMETER 1,5 mm AND OVER
Grade 1 or 2 ...	4	6
Grade 3 ...	2	3

### Certificates

911 Printed forms of certificates, approved by the Committee, are to be signed by the manufacturers and will be supplied to them on application.

## Section 10

### FIBRE ROPES

#### General

1001 Fibre ropes intended as mooring lines may be made of coir, hemp, manilla or sisal or may be composed of synthetic (man-made) fibres. They may be either 3-strand (hawser laid) 4-strand (shroud laid) or 9-strand (cable laid) but other constructions will be specially considered.

1002 Each length of rope is to be manufactured from suitable material of good and consistent quality. Rope materials should, in general, comply with a recognized National Standard.

1003 Synthetic fibre ropes are to be suitable for the purpose intended and should comply with a recognized Standard.

1004 Weighting and loading matter is not to be added and any added lubricant is to be kept to a minimum. Any rot-proofing or water repellancy treatment is not to be deleterious to the fibre nor is it to add to the weight or reduce the strength of the rope.

#### Testing

1005 The breaking load is to be determined by testing to destruction a sample cut from the completed rope.

1006 The minimum length of sample to be used in determining the breaking load of a fibre rope is to be as given in Table P 10.1. The specimen is to be loaded to the initial load, given in the Table as a percentage of the specified breaking load, and checked for diameter and evenness of lay-up. The load is then to be increased evenly and continuously at the rate shown in the Table until the specimen breaks.



If the sample is held by grips and the break occurs within 150 mm of the grips the test may be repeated but not more than two tests may be made on any one coil.

TABLE P 10.1 TESTING OF FIBRE ROPES

MATERIAL	TEST LENGTH mm	INITIAL LOADING	SPEED OF LOADING TO FRACTURE m/min
Natural Fibre	1800	2%	$0,15 \pm 0,05$
Synthetic Fibre	900	1%	0,10 maximum

1007 Where difficulty is experienced in testing a sample of a completed synthetic fibre rope the Society will consider alternative methods of testing.

#### Breaking Load

1008 The actual breaking load is not to be less than that given in an appropriate National Standard.

#### Certificates

1009 Printed certificates issued by the manufacturer or a competent government, municipal or similar responsible body will be accepted. The certificate should give the breaking load, test length and speed of testing.

### Section 11

#### APPROVAL OF ELECTRODES AND COMBINATIONS OF CONSUMABLES FOR WELDING IN HULL CONSTRUCTION

1101 The manufacturer's plant and method of production of electrodes and fluxes are to be such as to ensure reasonable uniformity in manufacture.

1102 Electrodes and wire-flux combinations will be approved subject to compliance with the following tests. The test pieces are to be prepared in the presence of the Surveyor and all tests carried out under his supervision.

#### ELECTRODES FOR MANUAL ARC WELDING

1103 Electrodes will be divided into Grades 1, 2 and 3 dependent on the results of the Charpy tests. In addition, if Grade 2 or Grade 3 electrodes comply with the requirements of the hydrogen test as given in 1114, a suffix H will be added to the Grade mark.

Electrodes which have satisfied the requirements of Grade 2 will also be considered as complying with Grade 1 requirements and those which have satisfied the requirements of Grade 3 will be considered as complying with Grades 1 and 2 requirements.

1104 Grade A hull structural steel may be used in the preparation of all test pieces, but at the option of the manufacturer Grades B, C or D steel may be used for Grade 2 electrode test pieces and Grade E steel for Grade 3 electrode test pieces.

Where approval is required for the welding of higher tensile steel of Grades AH, DH or EH, it is recommended that the butt weld assemblies be prepared using the appropriate grade of higher tensile steel (see 1107).

1105 The welding current used is to be within the range recommended by the manufacturer and, where an electrode is stated to be suitable for both a.c. and d.c., a.c. is to be used for the preparation of the test assemblies.

#### Deposited Metal Tests

1106 Tensile and impact tests are to be made, under controlled conditions, on metal deposited from the electrodes.

Two all-weld-metal test assemblies are to be prepared in the downhand position as shown in Fig. P 11.1, one using 4 mm electrodes and the other using 8 mm diameter electrodes or the largest size manufactured if this is less than 8 mm diameter.

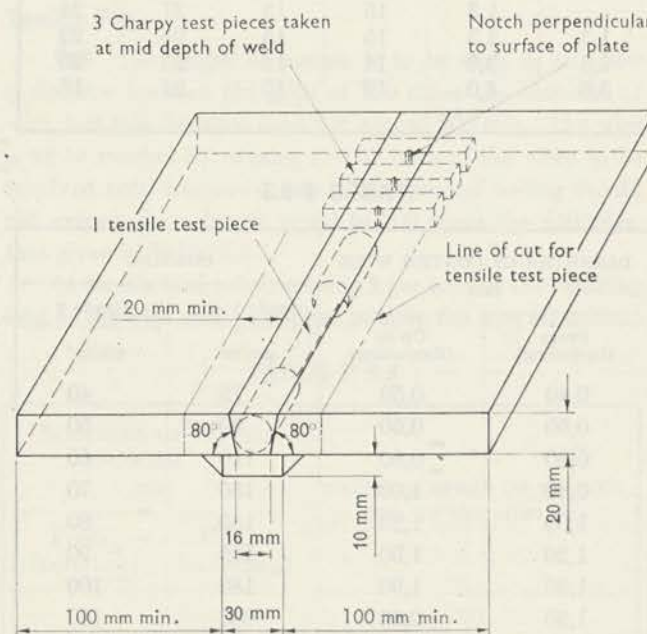


Fig. P 11.1



The weld metal is to be deposited in single or multi-run layers according to normal practice, and the direction of deposition of each layer is to alternate from each end of the plate, each run of weld metal being not less than 2 mm and not more than 4 mm thick. Between each run the assembly is to be left in still air until it has cooled to 250°C, the temperature being taken in the centre of the weld, on the surface of the seam.

After being welded the test assemblies are not to be subjected to any heat treatment.

#### Deposited Metal Tensile Tests

**1107** The tensile test pieces, one from each all-weld-metal assembly, are to be machined to the dimensions shown in Fig. P 11.2, care being taken that the longitudinal axis coincides with the centre of the weld, and the mid-thickness of the plates.

The tensile test piece may be subjected to a temperature not exceeding 250°C for a period not exceeding 16 hours for hydrogen removal, prior to testing.

Where approval is required for the welding of mild steel of Grades A, D or E, the tensile strength of each test specimen is not to be less than 400 N/mm<sup>2</sup> nor more than 560 N/mm<sup>2</sup>. Where this upper limit is exceeded special consideration will be given to the approval of the electrode, taking into consideration the other physical properties shown by the test results, and the chemical composition of the weld metal.

The yield stress is not to be less than 305 N/mm<sup>2</sup> and the elongation not less than 22 per cent on a gauge length of 50 mm.

Where approval is required for the welding of higher tensile steel of Grades AH, DH or EH the tensile strength is not to be less than 490 N/mm<sup>2</sup> nor more than 670 N/mm<sup>2</sup>. Where this upper limit is exceeded special consideration will be given as above.

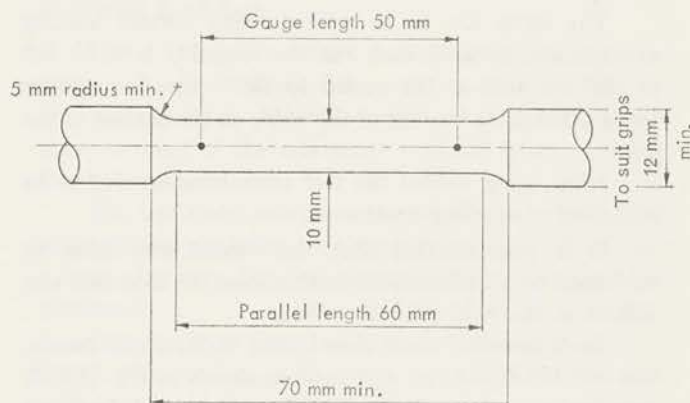


Fig. P 11.2

Alternatively, if the butt weld assemblies as required by 1109 are prepared using higher tensile steel of Grade AH, DH or EH as appropriate and provided the tensile strengths of the transverse tensile specimens as required by 1110 are not less than 490 N/mm<sup>2</sup> then the tensile strength of the deposited metal tensile test specimens may be lower than required above but must exceed 460 N/mm<sup>2</sup>.

The yield stress of the deposited metal tensile test specimens is not to be less than 355 N/mm<sup>2</sup> and the elongation not less than 22 per cent on a gauge length of 50 mm.

#### Deposited Metal Impact Tests

**1108** The impact test pieces are to be of the standard Charpy V-notch type in accordance with P 106 (d), three test pieces being taken from each of the deposited metal test assemblies. The test pieces shall be cut with their longitudinal axes perpendicular to the weld and the upper surface 5 mm from the upper surface of the plate.

The notch shall be positioned in the centre of the weld and is to be cut in the face of the test piece perpendicular to the surface of the plate.

For Grade 1 electrodes the average impact value for the three specimens from each assembly shall not be less than 47 J at about 20°C. The corresponding value for Grade 2 electrodes is 47 J at 0°C and for Grade 3 electrodes 61 J at -10°C or 47 J at -20°C. The test temperature for Grades 2 and 3 test pieces is to be controlled to within  $\pm 1$  degC of the prescribed temperature. Both the test specimen and the handling tongs are to be cooled for a sufficient length of time to reach the test temperature and the specimen then quickly transferred from the cooling device to the anvil of the testing machine and broken within a time lapse of not more than 5 seconds.

If the average of the three Charpy specimens fails to comply with the above requirements by an amount not exceeding 15 per cent of the required value, three additional test pieces may be made and tested, and the results added to those previously obtained to form a new average, which must comply with the requirements.

When the average value of the three Charpy specimens is more than 15 per cent below the required value, then six more Charpy test pieces are to be prepared and the average value of these new test pieces is to comply with the requirements.

The individual values of the Charpy specimens should be reasonably uniform and, to this end, a set of three Charpy specimens which meets the required average but which contains one or more values below 31 J when testing at 20°C, 0°C and -20°C or 41 J when testing at -10°C shall be disregarded and a further set of three specimens prepared and tested in its place.



The requirements for higher tensile steel approval do not differ from those given above.

### Butt Weld Tests

**1109** Butt weld assemblies as shown in Fig. P 11.3 are to be prepared for each welding position (downhand, horizontal-vertical, vertical and overhead) for which the electrode is recommended by the manufacturer, except that electrodes satisfying the requirements for downhand and vertical positions will be considered as also complying with the requirements for the horizontal-vertical position.

The test assemblies are to be made by welding together two plates 15 to 20 mm in thickness not less than 100 mm in width and of sufficient length to allow the cutting out of test specimens of the prescribed number and size. The plate edges are to be prepared to form a single vee joint, the

included angle between the fusion faces being  $60^\circ$  and the root gap 2 to 3 mm.

Where the electrode is to be approved only in the downhand position an additional test assembly is to be prepared in that position.

The following welding procedure should be adopted in making the test assemblies:—

Downhand (a). First run with 4 mm electrode. Remaining runs (except last two layers) with 5 mm electrodes or above according to the normal welding practice with the electrodes. The runs of the last two layers with the largest size of electrode manufactured or 8 mm whichever is the less.

Where a second downhand test is required:—

Downhand (b). First run with 4 mm electrode. Next run with an intermediate size electrode 5 mm or 6 mm and the remaining runs with the largest size of electrode manufactured or 8 mm whichever is the less.

Horizontal-vertical. First run with 4 mm or 5 mm electrode. Subsequent runs with 5 mm electrodes.

Vertical and overhead. First run with 3,15 mm electrode. Remaining runs with 4 mm electrodes or possibly with 5 mm electrodes if this is recommended by the manufacturer for the positions concerned.

If the electrode being tested is specially intended for vertical welding in the downward direction, then this technique should be adopted for the preparation of the vertical butt weld assembly, using electrode diameters as recommended by the manufacturer.

In all cases the back sealing runs are to be made with 4 mm electrodes in the welding position appropriate to each test sample, after cutting out the root run to clean metal. For electrodes suitable for downhand welding only, the test assemblies may be turned over to carry out the back sealing run.

The butts are to be welded using normal welding practice and between each run the assembly is to be left in still air until it has cooled to  $250^\circ\text{C}$  the temperature being taken in the centre of the weld, on the surface of the seam.

After being welded the test assemblies are not to be subjected to any heat treatment.

It is recommended that the welded assemblies be subjected to a radiographic examination to ascertain any defects in the weld prior to testing.

Each assembly shall then be cut to form one tensile, one face bend, and one root bend as shown in Fig. P 11.3, together with three Charpy specimens required from the downhand and vertical assemblies.

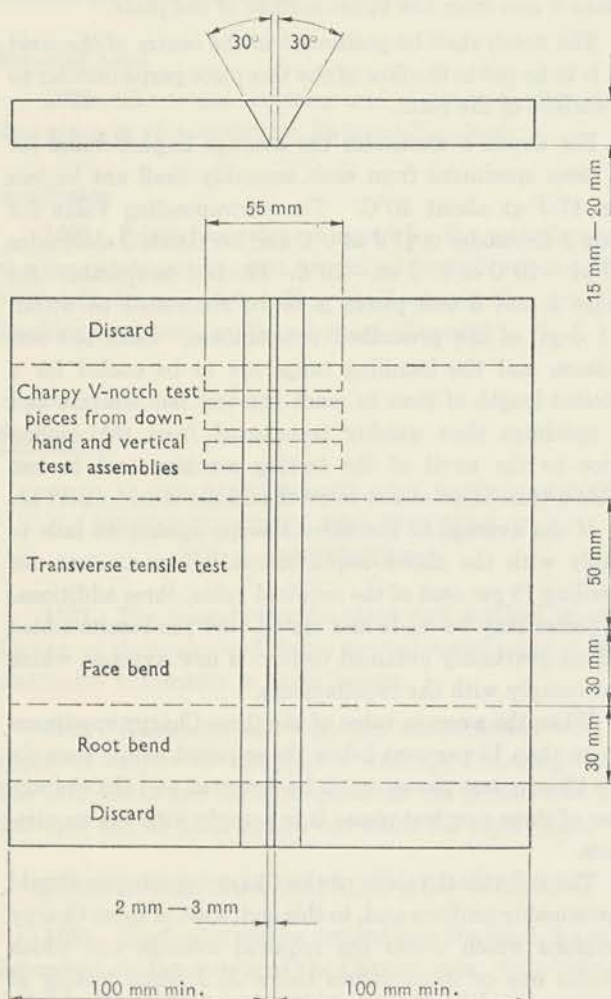


FIG. P 11.3



**Butt Weld Tensile Tests**

1110 Specimens of the form as shown in Fig. P 11.4 are to be prepared.

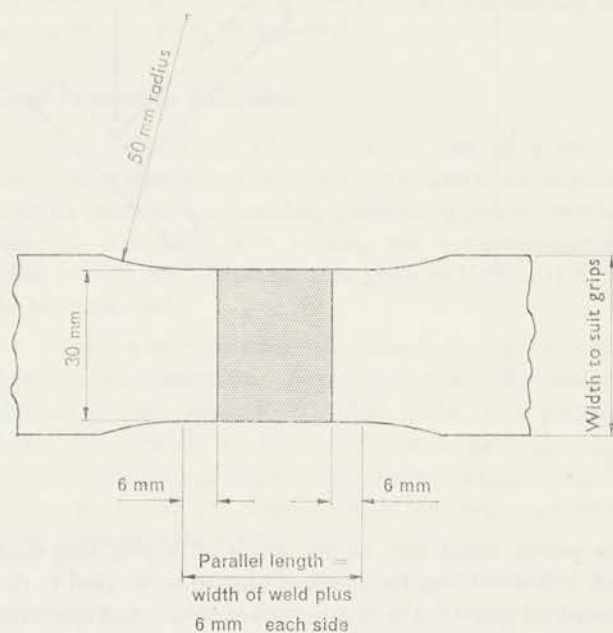


FIG. P 11.4

The upper and lower surfaces of the weld are to be filed, ground or machined flush with the surface of the plate.

The tensile strength of each test piece shall not be less than 400 N/mm<sup>2</sup>, for the welding of mild steel Grade A, D or E, and 490 N/mm<sup>2</sup> for the welding of higher tensile steel Grade AH, DH or EH in cases where the deposited metal tensile strength is below 490 N/mm<sup>2</sup> and butt welded assemblies are prepared using the appropriate grade of higher tensile steel (see 1107).

**Butt Weld Bend Tests**

1111 The specimens are to be 30 mm in width. The upper and lower surfaces of the weld are to be filed, ground or machined flush with the surface of the plate and the sharp corners of the specimens rounded to a radius not exceeding 2 mm.

The test specimens are to be capable of withstanding, without fracture, being bent through an angle of 120° over a former having a diameter three times the thickness of the specimen.

One specimen from each welded assembly is to be tested with the face of the weld in tension and the other with the root of the weld in tension.

The test pieces can be considered as complying with the

test if, on completion of the test, no crack or defect, at the outer surface of the test specimen, can be seen.

**Butt Weld Impact Tests**

1112 Three Charpy V-notch impact test pieces are to be machined from each of the downhand and vertical test assemblies.

The test pieces are to be prepared as shown in Fig. P 11.5 of the same dimensions as for the deposited metal impact tests.

The test specimens are to be taken from the middle of the plate thickness with the notch perpendicular to the surface of the plate as shown in Fig. P 11.5.

The average value of the results of the Charpy impact test pieces from the downhand assembly are to be in accordance with the requirements for deposited metal as given in 1108. The results from the vertical assembly are to be reported.

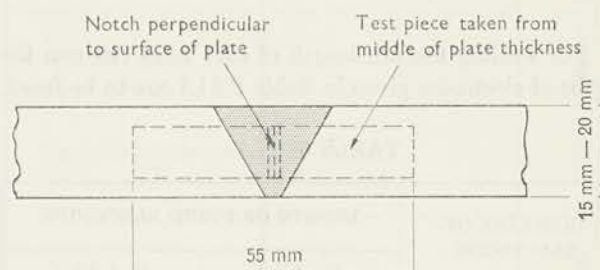


FIG. P 11.5

**Hot Cracking Test**

1113 Two plates 12 to 15 mm thick of dimensions 120 by 80 mm are to be welded together in the form of a square tee joint as shown in Fig. P 11.6. The lower face of the vertical plate is to be straight and is to fit closely on the plane surface of the lower plate. Any unevenness is to be removed before welding. The tack welds in preparation for the fillet welds are to be positioned at the two ends on a level with the contact surface of the plates. The lower plate is to be stiffened by three transverse stiffeners in order to prevent distortion.

The fillet welding, which is to be made in one pass, is to be carried out in the downhand position and the welding current used is to be the maximum of the range recommended by the manufacturer for the size of electrode used.

The second fillet weld is to be started immediately after the completion of the first fillet weld and at the end of the specimen at which the first fillet weld finished. Both fillet welds are to be executed at a constant speed and without weaving.

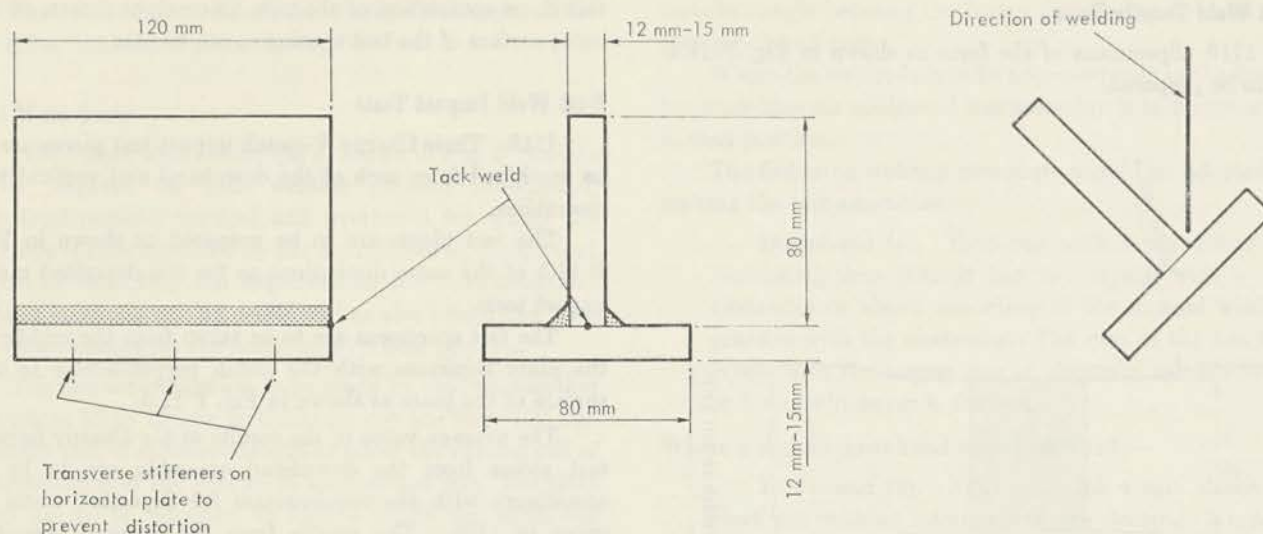


FIG. P 11.6

For welding the full length of each fillet 120 mm the lengths of electrodes given in Table P 11.1 are to be fused.

TABLE P 11.1

DIAMETER OF ELECTRODE	LENGTH OF FUSED ELECTRODE	
	1st fillet	2nd fillet
4 mm	200 mm	150 mm
5 mm	150 mm	100 mm
6 mm	100 mm	75 mm

After welding, the slag is to be removed from the fillet welds and after complete cooling they are to be examined for cracks by a magnifying glass or by the use of penetrant fluids.

The first fillet weld is then to be cut out by machining or gouging and the second weld broken by closing the two plates together, subjecting the root of the weld to tension. The weld shall then be examined for evidence of hot cracking. There should be no cracking in the fillet welds (except crater cracks) either superficial or internal.

#### Hydrogen Test

1114 Electrodes which have satisfied the requirements of Grade 2 or Grade 3 may, at the option of the manufacturer, be submitted to a hydrogen test, and a suffix H will be added to the Grade number to indicate compliance with the test requirements.

Four test specimens are to be prepared measuring 12 by 25 mm in cross section by about 125 mm in length.

The parent metal may be any grade of shipbuilding steel and, before welding, the specimens are to be weighed to the nearest 0.1 gm. On the 25 mm surface of each test specimen a single band of welding is to be deposited about 100 mm in length by a 4 mm electrode, using about 150 mm of the electrode. The welding is to be carried out with as short an arc as possible and with a current of about 150 amp.

The electrodes, prior to welding, can be submitted to the normal drying process recommended by the manufacturer.

Within 30 seconds of the completion of the welding of each specimen the slag is to be removed and the specimen quenched in water at approximately 20°C. After a further 30 seconds the specimens are to be cleaned and placed in an apparatus suitable for the collection of hydrogen by displacement of glycerine. The glycerine is to be kept at a temperature of 45°C during the test. All four specimens are to be welded and placed in the hydrogen collecting apparatus within 30 minutes.

The specimens are to be kept immersed in the glycerine for a period of 48 hours and, after removal, are to be cleaned in water and spirit, dried and weighed to the nearest 0.1 gm to determine the amount of weld deposited.

The amount of gas evolved is to be measured to the nearest 0.05 c.c. and corrected for temperature and pressure to 20°C and 760 mm Hg.

The amount of hydrogen in terms of cubic centimetres per gram of weld metal is to be reported and is not to exceed an average of 0.1 c.c. per gram for the four specimens tested.



Alternatively, the hydrogen content of the weld metal may be determined by any mercury gas burette type of apparatus, in accordance with a recognized procedure. Proposals for alternative methods of carrying out the test are to be submitted for approval.

#### Deep Penetration Electrodes

1115 Where, in addition to its use as a normal penetration electrode, a manufacturer desires to demonstrate that an electrode also has deep penetrating properties when used for downhand butt welding and horizontal-vertical fillet welding, the additional tests given in 1116 to 1120 are to be carried out.

Where a manufacturer recommends that an electrode having deep penetrating properties can also be used for downhand butt welding of thicker plates with prepared edges, the electrode will be treated as a normal penetration electrode and the full series of tests in the downhand position are to be carried out, together with the deep penetration tests given in 1116 to 1120.

Where an electrode is only recommended for deep penetration welding of butt joints and horizontal-vertical fillets, the tests given in 1116 to 1120 only are required to be carried out.

Deep penetration electrodes will only be approved as complying with Grade 1 requirements. The suffix D.P. will be added.

Where the manufacturer prescribes a different welding current and procedure for the electrode when used as a deep penetration electrode and a normal penetration electrode, the recommended current and procedure are to be used when making the test specimens in each case.

#### Deep Penetration Butt Weld Tests

1116 Two plates of thickness equal to twice the diameter of the core of the electrode plus 2 mm are to be butt welded together with one downhand run of welding from each side. The plates are not to be less than 100 mm wide and of sufficient length to allow the cutting out of the test specimens of the correct number and size as shown in Fig. P 11.7.

The joint edges are to be prepared square and smooth and, after tacking, the gap is not to exceed 0,25 mm.

The test assembly is to be welded using an 8 mm diameter electrode or the largest size manufactured if this is less than 8 mm.

After welding, the test assembly shall be cut to form two transverse tensile test pieces, two bend test pieces and three Charpy V-notch impact test pieces.

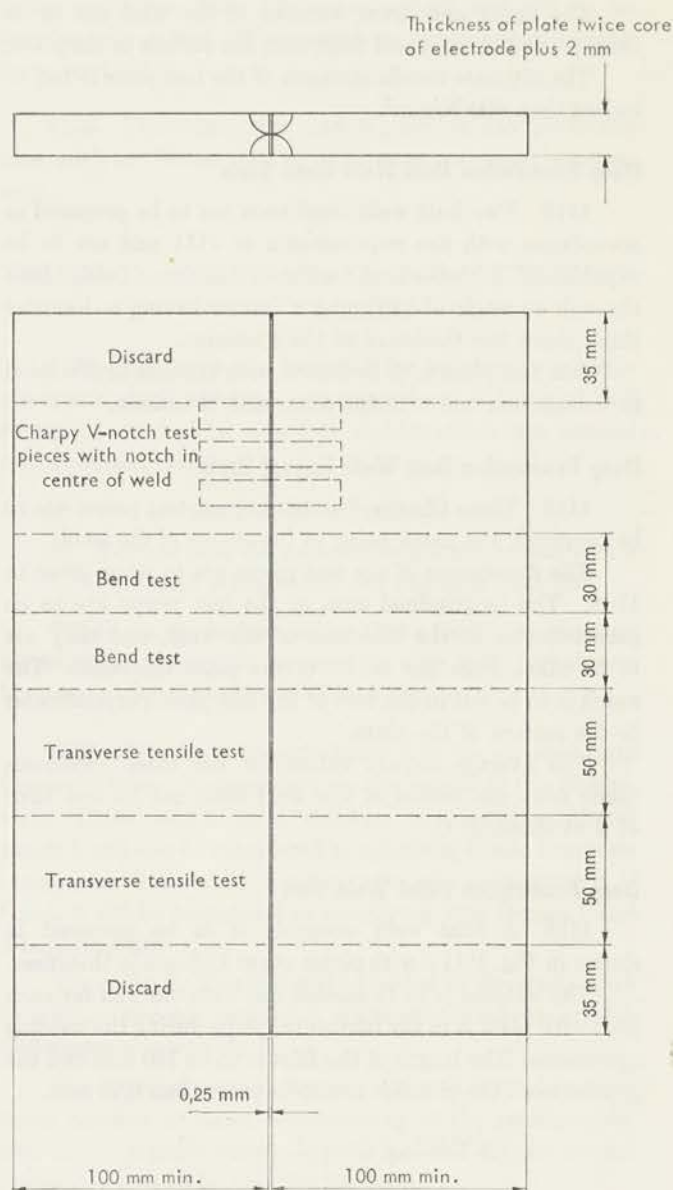


FIG. P 11.7

The discards at the end of the welded assemblies are to be not more than 35 mm wide. The joints of these discards are to be polished and etched and must show complete fusion and interpenetration of the welds. At each cut in the test assembly the joints are also to be examined to ensure that complete fusion has taken place.

#### Deep Penetration Transverse Butt Weld Tensile Test

1117 Two transverse butt weld tensile test specimens are to be prepared to the dimensions given in Fig. P 11.4.



The upper and lower surfaces of the weld are to be filed, ground or machined flush with the surface of the plate.

The ultimate tensile strength of the test piece is not to be less than 400 N/mm<sup>2</sup>.

#### Deep Penetration Butt Weld Bend Tests

**1118** Two butt weld bend tests are to be prepared in accordance with the requirements of 1111 and are to be capable of withstanding, without fracture, being bent through an angle of 120° over a former having a diameter three times the thickness of the specimen.

One test piece is to be tested with the side first welded in tension and one with the other side in tension.

#### Deep Penetration Butt Weld Impact Tests

**1119** Three Charpy V-notch impact test pieces are to be prepared, the notch being in the centre of the weld.

The dimensions of the test pieces are to be as given in 1108. The longitudinal axes of the test pieces are to be perpendicular to the direction of the weld, and they are to be taken from the centre of the plate thickness. The notch is to be cut in the face of the test piece perpendicular to the surface of the plate.

The average impact values for the three specimens taken from the centre of the weld shall not be less than 47 J at about 20°C.

#### Deep Penetration Fillet Weld Test

**1120** A fillet weld assembly is to be prepared as shown in Fig. P 11.8 with plates about 12,5 mm in thickness.

The welding is to be carried out with one run for each fillet with plate A in the horizontal plane during the welding operations. The length of the fillet is to be 160 mm and the gap between the plates is not to be more than 0,25 mm.

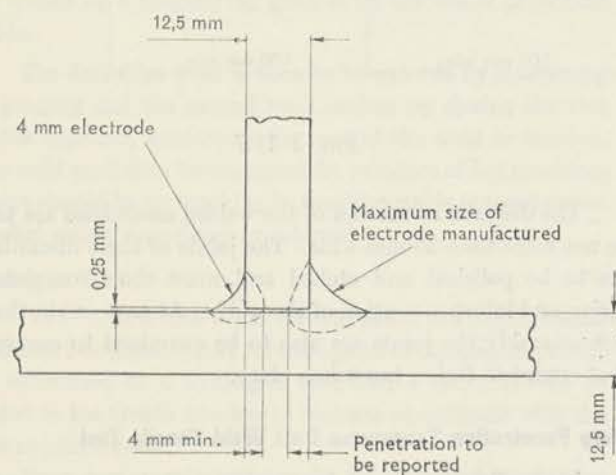


FIG. P 11.8

The fillet weld on one side of the assembly is to be carried out with a 4 mm electrode and that on the other side with the maximum size of electrode manufactured. The welding current used is to be within the range recommended by the manufacturer and the welding is to be carried out using normal welding practice.

The welded assembly is to be cut by sawing or machining within 35 mm of the ends of the fillet welds and the joints are to be polished and etched. The welding of the fillet made with a 4 mm electrode is to show a penetration of 4 mm (see Fig. P 11.8) and the corresponding penetration of the fillet made with the maximum size of electrode manufactured is to be reported.

#### Gravity Welding and Contact Welding

**1121** Where an electrode is submitted solely for approval for use in contact welding using automatic gravity or similar welding devices, the first approval testing should consist of deposited metal, butt weld and hot cracking tests similar to those for normal manual electrodes carried out using the process for which the electrode is recommended by the manufacturer.

Where an electrode is submitted for approval for use in contact welding using automatic gravity or similar welding devices in addition to normal manual welding, then the first approval testing is to be carried out as required by the Rules for manual arc welding. A hot cracking test, from which a macrograph should be taken, is also to be carried out using the gravity or other contact device as recommended by the manufacturer.

#### Chemical Analysis

**1122** The chemical analysis of the weld metal made by the electrode is to be supplied by the manufacturer.

**1123** The Committee is to be notified of any alteration proposed to be made in the process of manufacture subsequent to approval.

#### Maker's Certificate

**1124** Each carton or package of approved electrodes is to contain a certificate from the manufacturer on the following lines:—

"The ..... company certifies that the composition and quality of these electrodes conform with those of the electrodes used in making the test pieces submitted to and approved by the Committee of Lloyd's Register of Shipping".

#### Periodical Inspection of Maker's Works and Annual Tests

**1125** All establishments where approved electrodes are manufactured are to be subject to annual inspection. On



these occasions, samples of the approved electrodes are to be subjected to at least the following tests:—

One tensile and three impact specimens in duplicate are to be made from deposited metal as set forth in 1106, 1107 and 1108. One group of specimens is to be prepared using one size of electrode and one using another, neither size being smaller than 4 mm nor larger than 8 mm.

The tensile stress, yield stress and elongation are to be in accordance with 1107 and the impact properties in accordance with 1108 for the approved grade.

Where an electrode is approved for the welding of higher tensile steel, the tensile stress shall not be less than 460 N/mm<sup>2</sup>.

For electrodes approved for downhand deep penetration butts and horizontal vertical fillet welds the following tests are to be carried out:—

Two plates of thickness twice the core of the electrode plus 2 mm are to be butt welded together with one downhand run of welding from each side using a 6 mm electrode, or the largest size made if less than 6 mm. The plates are not to be less than 100 mm wide and of sufficient length to cut out one transverse tensile specimen, two bend test specimens and three Charpy V-notch impact specimens to the dimensions shown in Fig. P 11.7. The notch in the Charpy specimens is to be taken in the centre of the weld metal.

The dimensions of the test pieces and the requirements to be fulfilled are as set forth in the original approval tests in 1117, 1118 and 1119.

At each cut in the test assembly, the joints are to be examined to ensure that complete fusion has taken place.

For those electrodes which are approved for normal penetration welding and for deep penetration properties in the downhand position, these tests are to be carried out in addition to the deposited metal tests for normal penetration electrodes.

#### Upgrading

1126 Upgrading of electrodes will be considered only at the manufacturer's request, preferably at the time of annual testing. Charpy impact tests are to be carried out on specimens taken from butt welded assemblies as required by 1112 (downhand and vertical where applicable). This is in addition to the normal requirements for annual testing.

#### Additional Tests

1127 If any of the above tests fail, test pieces in duplicate of the same type are to be prepared (if possible

using electrodes from the same batch) and are to be satisfactorily tested. (For special requirements for Charpy tests, see 1108.)

1128 The Committee may require, in any particular case, such additional tests or requirements as may be necessary.

### WIRE-FLUX COMBINATIONS FOR SUBMERGED ARC WELDING

1129 The tests are intended for automatic or semi-automatic single electrode submerged arc welding of hull structural steel. The wire-flux combinations are divided into two categories:—

- (a) For use with the multi-run technique.
- (b) For use with the two-run technique; in this case a butt weld is made with one run from each side.

Where a manufacturer states that a particular wire-flux combination is suitable for welding with both techniques, both series of tests are to be carried out.

1130 Wire-flux combinations will be divided into Grades 1, 2 and 3, dependent on the results of the Charpy tests. Those which have satisfied the requirements of Grade 2 will also be considered as satisfying Grade 1 requirements and those which have satisfied the requirements of Grade 3 will be considered as complying with Grades 1 and 2 requirements.

The suffix T, M or TM will be added to the grade mark to indicate two-run technique, multi-run technique, or both techniques respectively.

The welding current may be either a.c. or d.c. (electrode positive or negative) according to the recommendation of the manufacturer. If both a.c. and d.c. are recommended, a.c. is to be used for the tests.

#### Multi-run Technique

1131 When approval for use with multi-run technique is required deposited metal and butt weld tests are to be carried out.

#### Deposited Metal Tests

1132 Tensile and impact tests are to be made, under controlled conditions, on metal deposited from the wire-flux combination.

An all-weld-metal test assembly is to be prepared in the downhand position as shown in Figs. P 11.9 and P 11.10, using any grade of hull structural steel.



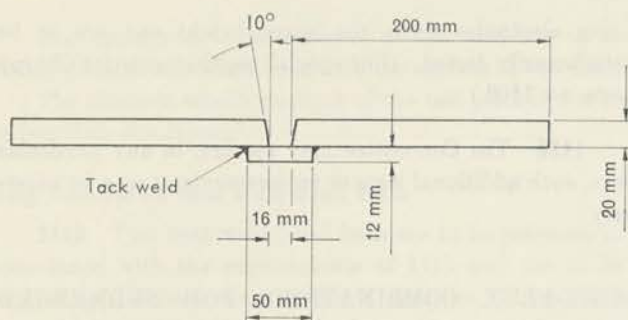


FIG. P 11.9

The bevelling of the plate edges is to be carried out by machining or mechanized gas cutting. In the latter case, any remaining scale is to be removed from the bevelled edges.

The direction of deposition of each run is to alternate from each end of the plate and after completion of each run the flux and welding slag is to be removed. Between each run the assembly is to be left in still air until it has cooled to 250°C, the temperature being taken in the centre of the weld, on the surface of the seam. The thickness of the layer is not to be less than the diameter of the wire but not less than 4 mm.

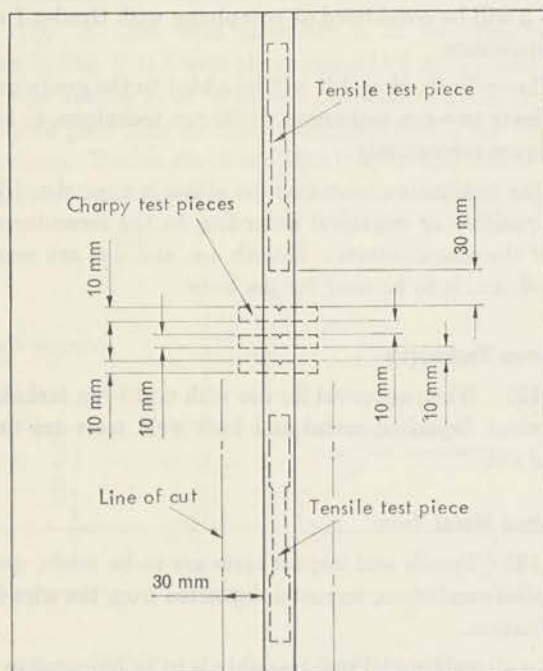


FIG. P 11.10

The welding conditions (amperage, voltage and rate of travel) are to be in accordance with the recommendations of the manufacturer and are to conform with normal, good welding practice for multi-run welding.

The welded assembly is to be cut longitudinally at a distance of 30 mm from the edges of the weld and then cut transversely.

#### Deposited Metal Tensile Tests

**1133** Two tensile test pieces are to be machined to the dimensions shown in Fig. P 11.2, care being taken that the longitudinal axis coincides with the centre of the weld, and the mid-thickness of the plates.

The tensile test pieces may be subjected to a temperature not exceeding 250°C for a period not exceeding 16 hours for hydrogen removal, prior to testing.

Where approval is required for the welding of mild steel of Grade A, D or E, the tensile strength of each test specimen is not to be less than 400 N/mm<sup>2</sup> nor more than 560 N/mm<sup>2</sup>. Where this upper limit is exceeded special consideration will be given to the approval of the wire-flux combination, taking into consideration the other physical properties shown by the test results, and the chemical composition of the weld metal.

The yield stress is not to be less than 305 N/mm<sup>2</sup> and the elongation not less than 22 per cent on a gauge length of 50 mm.

Where approval is required for the welding of higher tensile steel of Grade AH, DH or EH, the tensile strength is not to be less than 490 N/mm<sup>2</sup> nor more than 670 N/mm<sup>2</sup>. Where this upper limit is exceeded, special consideration will be given as above.

Alternatively, if the butt weld assembly as required by 1135 is prepared using higher tensile steel of Grade AH, DH or EH, as appropriate, and provided the tensile strengths of the transverse tensile specimens as required by 1136 are not less than 490 N/mm<sup>2</sup> then the tensile strength of the deposited metal tensile test specimens may be lower than required above but must exceed 460 N/mm<sup>2</sup>.

The yield stress of the deposited metal tensile test specimens is not to be less than 355 N/mm<sup>2</sup> and the elongation not less than 22 per cent on a gauge length of 50 mm.

#### Deposited Metal Impact Tests

**1134** The impact test pieces are to be of the Charpy V-notch type, three test pieces being taken from the deposited metal test assembly.

The dimensions of the test pieces are to be as given in 1108.



The test pieces are to be cut with their longitudinal axes perpendicular to the weld and the upper surface 5 mm from the upper surface of the plate. The notch is to be positioned in the centre of the weld and is to be cut in the face of the test pieces perpendicular to the surface of the plate as shown in Fig. P 11.10. The tests are to be carried out on an approved Charpy impact machine.

Where approval is required for the welding of mild steel of Grade A, D or E, for Grade 1 combinations the average impact value of the specimens shall not be less than 34 J at about 20°C. The corresponding value for Grade 2 combinations is 34 J at 0°C and for Grade 3 combinations 44 J at -10°C, or 34 J at -20°C.

The individual values of the Charpy specimens should be reasonably uniform and, to this end, a set of three Charpy specimens which meets the required average but which contains one or more values below 24 J when testing at 20°C, 0°C or -20°C, or 29 J when testing at -10°C, should be disregarded and a further set of three specimens prepared and tested in its place.

Where approval is required for the welding of higher tensile steel Grade AH, DH or EH, for Grade 1 combinations the average impact value of the specimens shall not be less than 39 J at about 20°C. The corresponding value for Grade 2 combinations is 39 J at 0°C, and for Grade 3 combinations 51 J at -10°C, or 39 J at -20°C.

A set of three Charpy values which meets the required average but which contains one or more values below 26 J when testing at 20°C, 0°C or -20°C, or 34 J when testing at -10°C should be disregarded and a further set of three specimens prepared and tested in its place.

The test temperature for Grades 2 and 3 test pieces is to be controlled to within  $\pm 1$  degC of the prescribed temperature and the test procedure laid down in 1108 is to be followed.

#### Butt Weld Tests

**1135** A butt weld assembly as shown in Fig. P 11.11 is to be prepared in the downhand position by welding together two 20 mm plates not less than 150 mm in width and of sufficient length to allow the cutting out of test specimens of the prescribed number and size.

For Grades 1 and 2 wire-flux combinations Grade A steel is to be used, and for Grade 3 wire-flux combinations any grade of steel may be used.

Where approval is required for the welding of higher tensile steel of Grade AH, DH or EH, it is recommended that the butt weld assembly be prepared using the appropriate grade of higher tensile steel (*see* 1133).

The plate edges are to be prepared to form a single vee

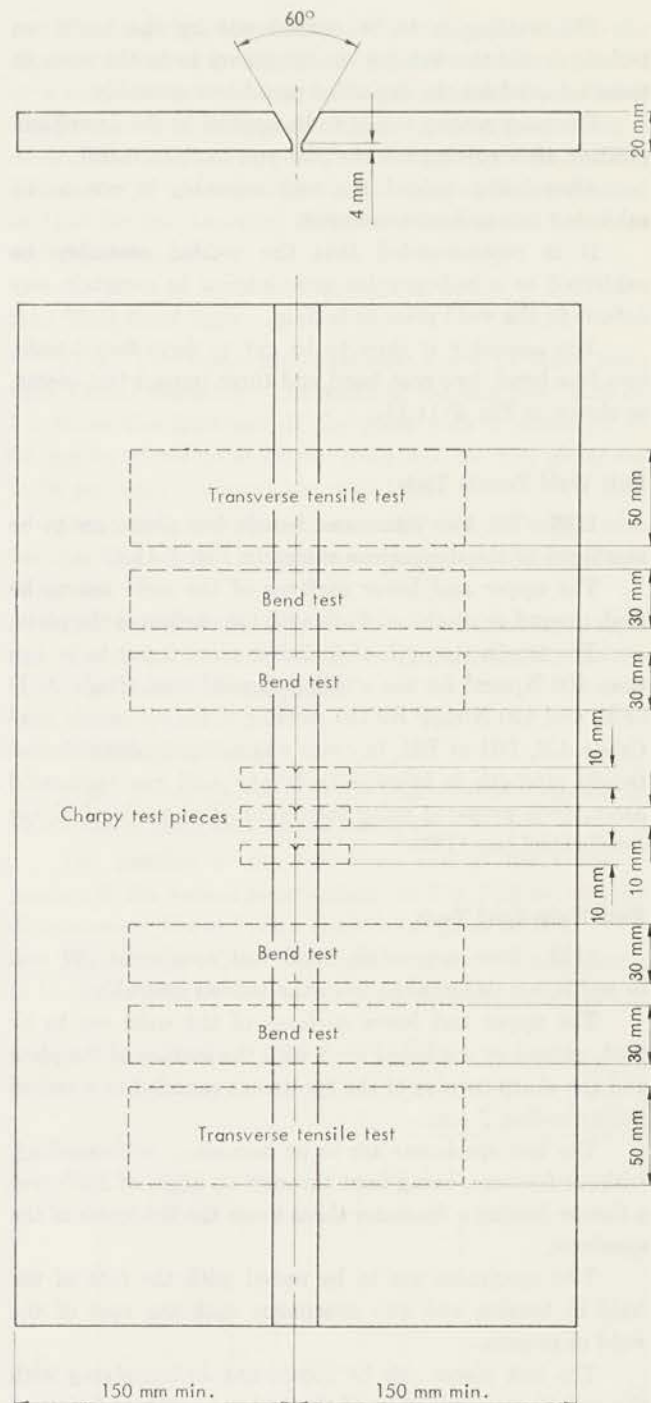


FIG. P 11.11

joint, the included angle between the fusion faces being 60° and the root face being 4 mm. The bevelling of the plate edges is to be carried out by machining or mechanized gas cutting. In the latter case, any remaining scale is to be removed from the bevelled edges.



The welding is to be carried out by the multi-run technique and the welding conditions are to be the same as those adopted for the deposited metal test assembly.

The back sealing run is to be applied in the downhand position after cutting out the root run to clean metal.

After being welded the test assembly is not to be subjected to any heat treatment.

It is recommended that the welded assembly be subjected to a radiographic examination to ascertain any defects in the weld prior to testing.

The assembly is then to be cut to form two tensile, two face bend, two root bend and three impact test pieces, as shown in Fig. P 11.11.

#### Butt Weld Tensile Tests

**1136** The two transverse tensile test pieces are to be machined to the dimensions shown in Fig. P 11.4.

The upper and lower surfaces of the weld are to be filed, ground or machined flush with the surface of the plate.

The tensile strength of each test piece is not to be less than 400 N/mm<sup>2</sup> for the welding of mild steel Grade A, D or E, and 490 N/mm<sup>2</sup> for the welding of higher tensile steel Grade AH, DH or EH, in cases where the deposited metal tensile strength is below 490 N/mm<sup>2</sup> and the butt weld assembly is prepared using the appropriate grade of higher tensile steel (*see* 1133).

#### Butt Weld Bend Tests

**1137** Four transverse bend test specimens, 30 mm in width, are to be taken from the welded assembly.

The upper and lower surfaces of the weld are to be filed, ground or machined flush with the surface of the plate and the sharp corners of the specimens rounded to a radius not exceeding 2 mm.

The test specimens are to be capable of withstanding, without fracture, being bent through an angle of 120° over a former having a diameter three times the thickness of the specimen.

Two specimens are to be tested with the face of the weld in tension and two specimens with the root of the weld in tension.

The test pieces can be considered as complying with the test if, on completion of the test, no crack or defect at the outer surface of the test specimen can be seen.

#### Butt Weld Impact Tests

**1138** Three Charpy V-notch impact test pieces are to be machined from the test assembly.

The test specimens are to be prepared as shown in Fig. P 11.5, to the dimensions given in 1108. The test

specimens are to be taken from the middle of the plate thickness with the notch perpendicular to the surface of the plate.

The average value of the results of the Charpy impact tests is to be in accordance with the requirements for deposited metal given in 1134.

#### Two-run Technique

**1139** Two welded assemblies are to be prepared in accordance with Fig. P 11.12 using the following plate thickness:—

For Grade 1 approval—12 to 15 mm and 20 mm.

For Grades 2 and 3 approval—20 mm and 35 mm.

Where approval is required for the welding of higher tensile steel Grade AH, DH or EH, two assemblies are to be prepared using higher tensile steel in addition to the two assemblies using mild steel.

**1140** The maximum diameter of wire, grades of steel plate and edge preparation to be used are to be in accordance with Fig. P 11.13. Small deviations in the edge preparation may be allowed if requested by the manufacturer. The bevelling of the plate edges is to be performed by machining or mechanized gas cutting. In the latter case any remaining scale is to be removed from the bevelled edges. The root gap should not exceed 0.7 mm.

Each butt weld is to be welded in two runs, one from each side, using amperages, voltages and travel speeds in accordance with the recommendations of the manufacturer and normal good welding practice.

After completion of the first run, the flux and welding slag are to be removed and the assembly is to be left in still air until it has cooled to 100°C, the temperature being taken in the centre of the weld, on the surface of the seam.

After being welded the test assemblies are not to be subjected to any heat treatment.

It is recommended that the welded assemblies be subjected to radiographic examination to ascertain any defects in the weld prior to testing.

The assemblies shall each be cut transversely to form two tensile test pieces, two bend test pieces and three impact test pieces as shown in Fig. P 11.12. The edges of two of the discards are to be polished and etched, and must show complete fusion and interpenetration of the welds. At each cut in the test assembly, the edges are also to be examined to ensure that complete fusion has taken place.

Where the combination is to be used for two-run technique only, a longitudinal tensile test is also to be made in accordance with Fig. P 11.12 on the thicker plate tested.



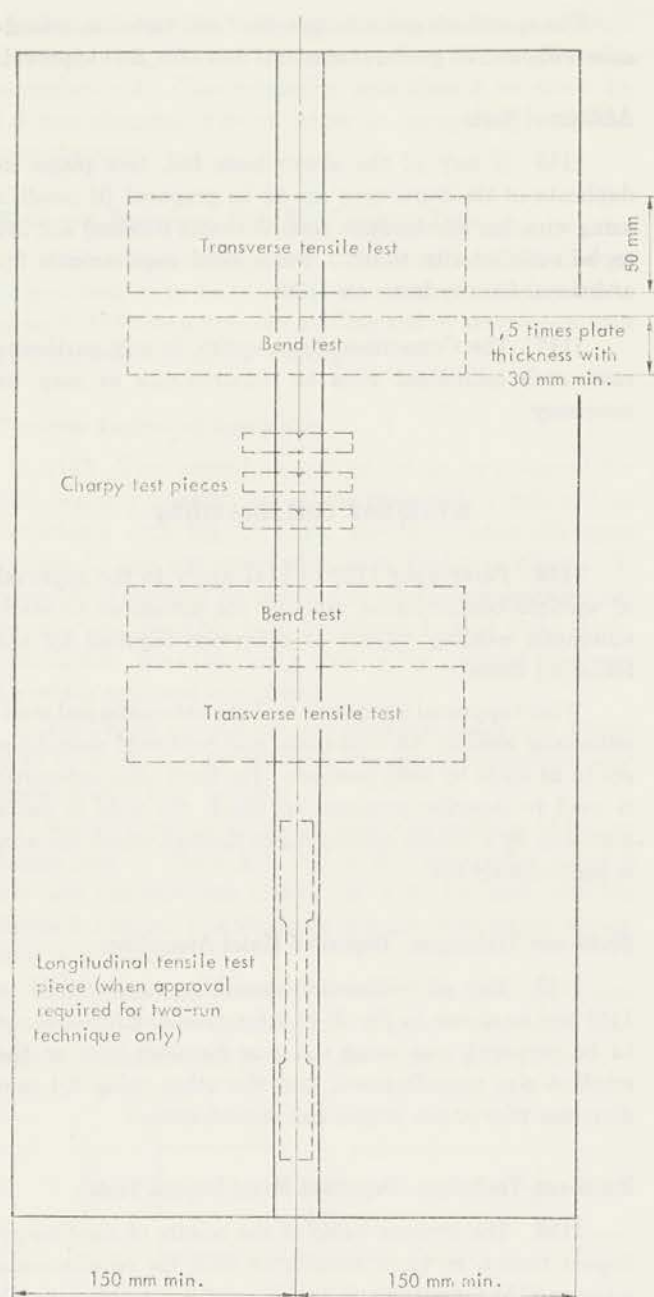


Fig. P 11.12

**Butt Weld Tensile Tests**

**1141** The two tensile test pieces cut transversely from each welded assembly are to be prepared as set forth in 1136 for multi-run technique.

The tensile strength of each test piece is not to be less than 400 N/mm<sup>2</sup> for the welding of mild steel Grade A, D or E, and 490 N/mm<sup>2</sup> for the welding of higher tensile steel Grade AH, DH or EH.

The longitudinal tensile piece is to be machined to the dimensions shown in Fig. P 11.2, and the longitudinal axis is to coincide with the centre of the weld about 7 mm below the plate surface on the side from which the second run is made. The test piece may be heat treated as set out in 1133. The results of the test are to be the same as those specified in 1133 for the deposited metal tensile tests for multi-run technique test pieces.

**Butt Weld Bend Tests**

**1142** Two transverse bend tests are to be taken from each welded assembly. The width of the test piece is to be 1.5 times the thickness of the plate with a minimum of 30 mm for plates up to 20 mm thick, and the test pieces are to be prepared in accordance with 1137.

One specimen from each assembly is to be tested with the side first welded in tension and one with the other side in tension.

The results of the tests and the conditions for acceptance are to be the same as those specified in 1137 for the multi-run technique test pieces.

**Butt Weld Impact Tests**

**1143** Three Charpy V-notch impact test pieces are to be machined from each welded assembly.

The position of the test piece and of the notch in relation to the welded seam is shown in Fig. P 11.14, and the dimensions of the test piece are to be as given in 1108.

The average value of the results of the Charpy tests is to be in accordance with the requirements given in 1134.

Plate thickness	Preparation	Maximum diameter of wire	Grade of wire/flux combination	Grade of mild steel	Grade of higher tensile steel
12mm -- 15mm		5mm	1	A	AH
20mm		6mm	1	A	AH
			2	A	AH or DH
			3	C, D or E	AH, DH or EH
35mm		7mm	2	B, C or D	AH or DH
			3	C, D or E	AH, DH or EH

Fig. P 11.13

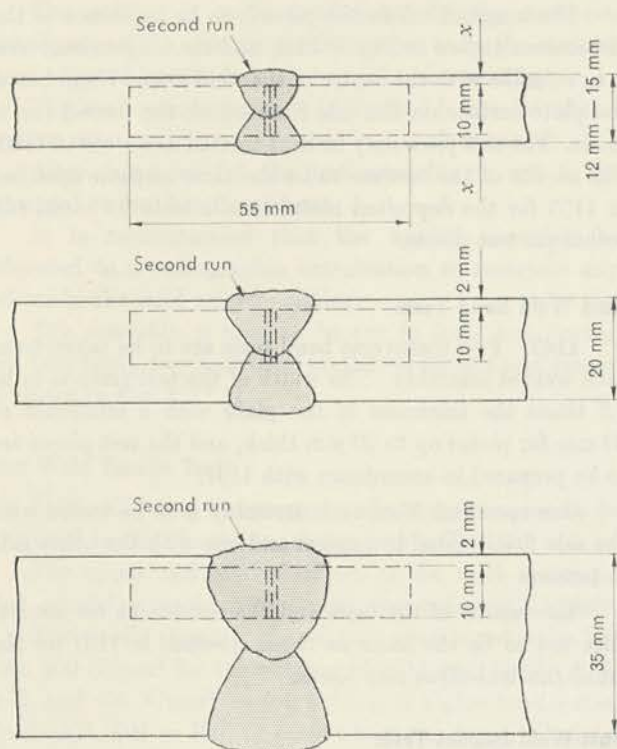


FIG. P 11.14

### Chemical Analysis

1144 The chemical analysis of the weld metal made by the wire-flux combination is to be supplied by the manufacturer.

The plate material used is to have an analysis which is representative of the grade of steel laid down for the test.

### Periodical Inspection of Maker's Works and Annual Tests

1145 All establishments where approved electrodes are manufactured shall be subject to annual inspection. On these occasions, samples of the approved wire-flux combinations shall be subject to at least the following tests:—

#### MULTI-RUN TECHNIQUE:—

Deposited metal tests—two tensile and three impact tests. Where a combination is approved for the welding of higher tensile steel, the tensile strength shall not be less than 460 N/mm<sup>2</sup>.

#### TWO-RUN TECHNIQUE:—

Transverse specimens taken from a 20 mm butt weld assembly—two tensile, two bend and three impact tests. Where a combination is approved for the welding of higher tensile steel, the assembly is to be prepared using higher tensile steel.

The specimens are to be prepared and tested in accordance with, and on grades of steel laid down for, first approval.

### Additional Tests

1146 If any of the above tests fail, test pieces in duplicate of the same type are to be prepared (if possible using wire-flux combination from the same batches) and are to be satisfactorily tested. For special requirements for additional Charpy tests, see 1108.

1147 The Committee may require, in any particular case, such additional tests or requirements as may be necessary.

### WIRE/GAS COMBINATIONS

1148 Paragraphs 1129 to 1147 apply to the approval of wire/gas combinations, whether for automatic or semi-automatic welding, except as otherwise required by the following Rules.

Where approval is required for both automatic and semi-automatic welding, all-weld-metal and butt weld assemblies are to be made by both methods. The term semi-automatic is used to describe processes in which the weld is made manually by a welder holding a gun through which the wire is continuously fed.

### Multi-run Technique. Deposited Metal Assemblies

1149 Two all-weld-metal assemblies as described in 1132 and as shown in Fig. P 11.1 for manual electrodes are to be prepared, one using 0,8 mm diameter wire or the smallest size manufactured, and the other using 2,4 mm diameter wire or the largest size manufactured.

### Multi-run Technique. Deposited Metal Impact Tests

1150 The average value of the results of the Charpy impact tests is to be in accordance with the requirements given in 1134 for automatic welding and in accordance with 1108 for semi-automatic welding.

### Multi-run Technique. Butt Weld Assemblies

1151 Butt weld assemblies, as shown in Fig. P 11.3 for manual electrodes, are to be prepared for each welding position (downhand, vertical and overhead) for which the combination is recommended by the manufacturer.

Where the combination is to be approved in the downhand position only, an additional test assembly is to be prepared in that position.



In preparing the welded assemblies the first run should be made using 0,8 mm diameter wire or the smallest size manufactured. The remaining runs should be made by 1,2 mm diameter wire or larger as recommended by the manufacturer.

#### Multi-run Technique. Butt Weld Impact Tests

1152 The average value of the results of the Charpy impact tests is to be in accordance with the requirements given in 1134 for automatic welding and in accordance with 1108 for semi-automatic welding.

#### Two-run Technique Assemblies

1153 Two welded assemblies are to be prepared for each welding position for which approval is required in accordance with Fig. P 11.12, one using plate thickness 12 mm–15 mm the other using plate thickness 20 mm. If approval is required for welding of thicknesses greater than 20 mm, one assembly is to be prepared using plate thickness 20 mm, the other using plate of the greatest thickness for which approval is required.

For Grades 1 and 2 wire/gas combinations Grade A steel is to be used, and for Grade 3 wire/gas combinations any grade of steel may be used.

Where approval is required for the welding of higher tensile steel of Grade AH, DH or EH, for Grades 1 and 2 wire/gas combinations Grade AH is to be used, and for Grade 3 wire/gas combinations any grade of higher tensile steel may be used.

The maximum diameter of wire to be used is 1,6 mm or the smallest size manufactured if greater than this. The edge preparations are to be as shown in Fig. P 11.15.

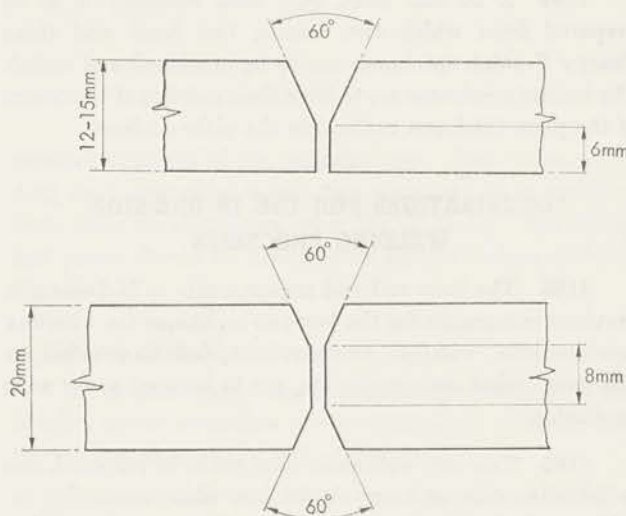


FIG. P 11.15

For assemblies using plate thickness over 20 mm the edge preparation and wire diameter proposed are to be submitted.

#### Two-run Technique. Butt Weld Impact Tests

1154 The average value of the results of the Charpy impact tests is to be in accordance with the requirements given in 1134 for automatic welding and in accordance with 1108 for semi-automatic welding.

#### Hot Cracking Test

1155 If the wire/gas combination is recommended by the manufacturer for fillet welding a hot cracking test is to be carried out.

The testing procedure as described in 1113 is to be followed, and for welding the full length of each fillet, 120 mm, the approximate lengths of wires given in Table P 11.2 are to be fused.

TABLE P 11.2

DIAMETER OF WIRE	LENGTH OF FUSED WIRE	
	1st fillet	2nd fillet
0,8 mm	4800 mm	3600 mm
1,2 mm	2000 mm	1500 mm
1,6 mm	1200 mm	900 mm

#### Annual Tests

1156 (a) Wire/gas combinations approved for automatic welding only:—

Multi-run technique—tests as required by 1145. For the preparation of the deposited metal assembly, the wire diameter should be about the centre of the range of diameters manufactured. Two-run technique—tests as required by 1145. For the preparation of the butt weld assembly, the wire diameter should be as recommended by the manufacturer and the thickness of the assembly should be the maximum for which the combination is approved in the two-run technique.

(b) Wire/gas combinations approved for semi-automatic welding only:—

Two deposited metal assemblies are to be prepared and tested as required by 1125, one using 0,8 mm diameter wire or the smallest



size manufactured, and the other using 2,4 mm diameter wire or the largest size manufactured.

If the combination is approved for semi-automatic welding in the two-run technique an assembly as described in (a) above is to be prepared and tested.

(c) Wire/gas combinations approved for both automatic and semi-automatic welding:—

The annual tests should be carried out as described in (b) above using the semi-automatic process for welding the assemblies.

#### FLUX-CORED OR FLUX-COATED WIRES WITH OR WITHOUT SHIELDING GAS

1157 Paragraphs 1148 to 1156 for wire/gas combinations apply also to the approval of flux-cored or flux-coated wires with or without shielding gas except as otherwise required by the following Rules.

1158 Where more than one diameter of wire is produced, the diameters to be used in the preparation of the all-weld-metal assemblies, the multi-run and two-run butt weld assemblies and the hot cracking test assembly are to be agreed before welding commences.

1159 If flux-cored or flux-coated wires with or without shielding gas are recommended by the manufacturer for use in applications requiring low hydrogen content, then the wires should be submitted to the hydrogen test, as set out in 1114, adapted to suit the process. A suffix H will be added to the grade number to indicate compliance with the test requirements.

#### COMBINATIONS FOR USE IN ELECTRO-SLAG AND ELECTRO-GAS WELDING

1160 Paragraphs 1139 to 1147 apply to the approval of combinations for use in electro-slag and electro-gas welding with or without consumable nozzles, except as otherwise required by the following Rules.

1161 Two welded assemblies are to be prepared, one in 20 mm thick plate and the other in 35 mm thick plate. The grade of steel to be used for each of these assemblies is to be in accordance with Fig. P 11.13.

The welding conditions and the edge preparation adopted are to be in accordance with the recommendations of the manufacturer.

1162 Each assembly is to be cut to form test pieces as follows:—

Two longitudinal tensile test pieces from the centre of the weld.

Two longitudinal tensile test pieces with their axes on the fusion line.

Two transverse tensile test pieces.

One root bend test piece.

One face bend test piece.

Three Charpy V-notch test pieces with their notches in the centre of the weld.

Three Charpy V-notch test pieces with their notches 2 mm from the fusion line in the weld metal.

Three Charpy V-notch test pieces with their notches 2 mm from the fusion line in the heat affected zone.

Three Charpy V-notch test pieces with their notches in the parent plate away from the weld.

One macrograph of the weld.

The test pieces are to be arranged as shown in Fig. P 11.16.

#### Additional Charpy Impact Tests

1163 Where approval is required for the welding of higher tensile steel of Grade AH, DH or EH, approval is given either for use only with aluminium treated fine grain steel or for use with aluminium and niobium treated steels. For the latter approval the butt assembly should be prepared using niobium treated steel.

#### Annual Tests

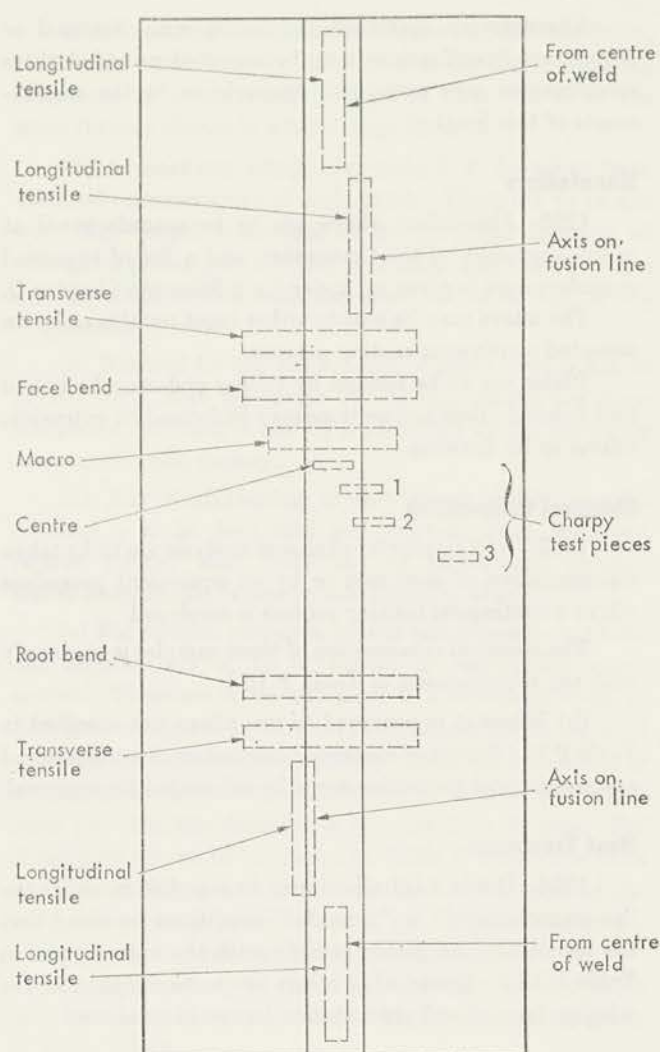
1164 A 20 mm thick butt weld assembly is to be prepared from which two tensile, two bend and three Charpy V-notch specimens are to be machined and tested. The impact specimens are to have their notches at the centre of the plate thickness vertical to the plate surfaces.

#### COMBINATIONS FOR USE IN ONE-SIDE WELDING PROCESSES

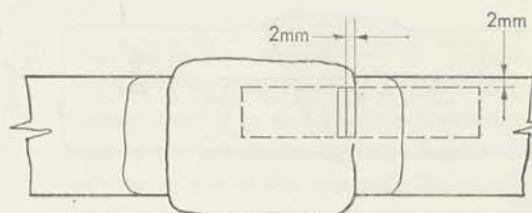
1165 The tests and test requirements as laid down in previous paragraphs for the two-run technique for wire/flux combinations, wire/gas combinations and flux-coated or flux-cored wires, as appropriate, are to be used so far as is applicable.

1166 Two butt weld assemblies are to be prepared, one in 20 mm plate and one in 35 mm plate (assuming no thickness limitation is to be applied). The edge preparation and welding conditions are to be in accordance with the

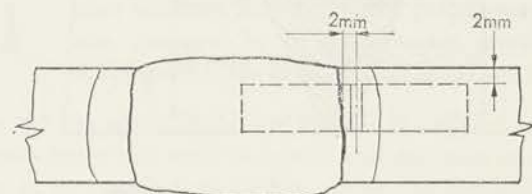




(1) In the weld metal 2 mm from the fusion line.



(2) In heat affected zone 2 mm from the fusion line.



(3) In workpiece remote from weld.

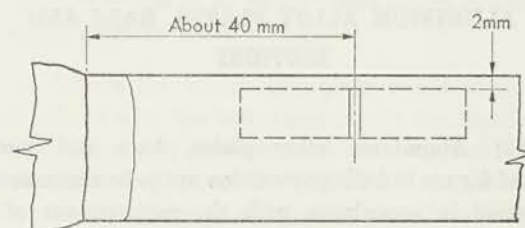


FIG. P 11.16

recommendations of the manufacturer. Test pieces (including the longitudinal tensile test piece) are to be machined from these in accordance with Fig. P 11.12. The Charpy test pieces should be arranged as follows and as shown in Fig. P 11.17.

**(a) 20 mm Assembly**

1. A set of three Charpy impact test pieces with their notches in the centreline of the weld taken at 2 mm from the plate surface at the root of the weld.

2. A set of three Charpy impact test pieces with their notches in the centreline of the weld taken at 2 mm from the plate surface at the face of the weld.

**(b) 35 mm Assembly**

1 and 2 as above for 20 mm assembly.

3. A set of three Charpy impact test pieces with their notches in the centreline of the weld taken at the middle of the plate thickness.

One macrograph should be taken from each assembly.

**1167** Annual testing is to be carried out in accordance with 1145 for the two-run technique. The three impact test pieces are to be taken with their notches in the centreline of the weld, 2 mm from the plate surface at the root of the weld.

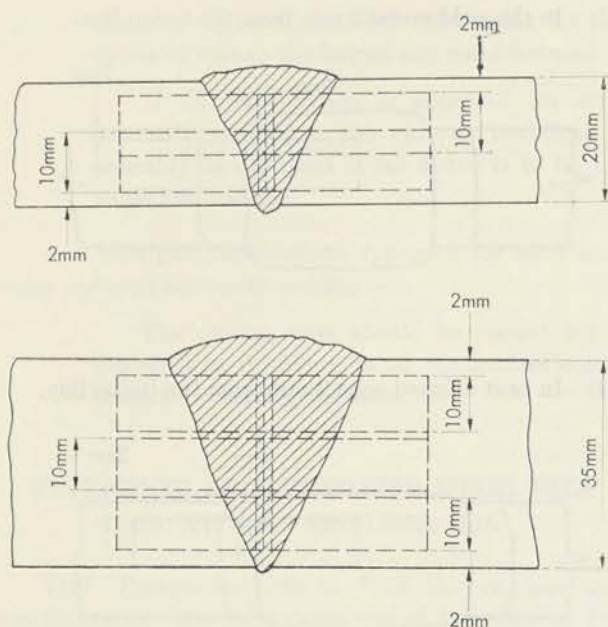


FIG. P 11.17

## Section 12

### ALUMINIUM ALLOY PLATES, BARS AND SECTIONS

#### Scope

**1201** Aluminium alloy plates, bars and sections intended for use in hull construction are to be manufactured and tested in accordance with the requirements of this Section. These requirements do not apply to plates less than 4,5 mm thick or to angles and other sections less than 40×40×4,5 mm. Where thin material of this type is used, the mechanical properties and chemical composition are to be in accordance with a recognized National Specification for an aluminium alloy suitable for marine use.

Alternatively, materials complying with National or proprietary Specifications may be accepted provided these specifications give reasonable equivalence to the requirements of this Section.

#### Manufacture

**1202** Aluminium alloys are to be manufactured at works approved by the Committee, and a list of approved manufacturers is given in Appendix 2 following Chapter Q.

The alloys may be cast in either ingot moulds or by an accepted continuous casting process.

Plates are to be formed by rolling and may be hot or cold finished. Bars and sections may be formed by extrusion, rolling or by drawing.

#### Chemical Composition

**1203** (a) Samples for chemical analysis are to be taken representative of each cast or by an equivalent procedure where a continuous melting process is employed.

The chemical composition of these samples is to comply with the requirements of Table P 12.1.

(b) Where it is proposed to use alloys not specified in Table P 12.1 details of chemical composition, heat treatment and mechanical properties are to be submitted for approval.

#### Heat Treatment

**1204** Grade AL 1 alloys may be supplied in either the "as manufactured" or "annealed" conditions provided that the mechanical properties comply with the values given in Table P 12.3. Grade AL 2 alloys are to be supplied in the solution treated and precipitation hardened condition.

#### Test Material

**1205** (a) Material of the same section and thickness, produced in the same way and of the same nominal chemical composition, is to be presented for testing in batches of not more than 4 tonnes.

TABLE P 12.1

CONSTITUENT	GRADE AL 1	GRADE AL 2
Copper	0,10% max.	0,10% max.
Magnesium	3,5-5,6%	0,4-1,4%
Silicon	0,5% max.	0,6-1,6%
Iron	0,5% max.	0,5% max.
Manganese	1,0% max.	0,2-1,0%
Zinc	0,2% max.	0,2% max.
Chromium	0,35% max.	0,35% max.
Titanium and other grain refining elements	0,2% max.	0,2% max.
Aluminium	The remainder	The remainder



If the material is supplied in the heat treated condition, then each batch is to be subjected to the same finishing treatment in a continuous furnace or heat treated in the same furnace charge in a batch type furnace.

(b) At least one tensile test piece is to be taken from material representative of each batch. These are to be cut with their length transverse to the principal direction of rolling for plates over 300 mm in width. For narrow plates and for sections and bars the tests are to be cut in the longitudinal direction.

(c) Material for the preparation of these tests is not to be cut until heat treatment (where applicable) has been completed nor until it has been identified by the Surveyor or an authorized deputy.

(d) Any straightening of test pieces which may be required is to be done cold and the test pieces shall not receive further heat treatment or mechanical working before being tested except by machining to shape.

(e) For routine purposes, tensile test pieces from plates and sections are to be of square or rectangular cross-section. These are to be machined to a minimum width of 12,0 mm and are to be of the full thickness of the material with the wrought surfaces retained. Machined test pieces of circular cross-section may, however, be used as an alternative provided the diameter is not less than 10 mm. The dimensions are to be as shown in Table P 12.2. The ends may be machined in a form suitable for the grips of the testing machine provided there is an adequate radius between the test length and the enlarged ends.

Round bars may be tested in full section or test pieces may be machined in accordance with the dimensions given in Table P 12.2.

#### Mechanical Properties

1206 (a) All tests are to be carried out in the presence of the Surveyor or an authorized deputy. The 0,2 per cent proof stress, tensile strength and percentage elongation are to be determined.

(b) The 0,2 per cent proof stress is to be determined by either:—

(i) drawing a line parallel to the straight elastic portion of an accurate load/extension diagram and distant from it by an amount representing 0,2 per cent of the extensometer gauge length. The point or intersection of this line with the plastic portion of the diagram represents the proof load, from which the 0,2 per cent proof stress can be calculated;

or (ii) subjecting the test piece to the specified minimum proof stress and removing the load when the test piece shall not have acquired a permanent elongation, measured by an extensometer, greater than 0,2 per cent of the extensometer gauge length.

(c) The rate of increase of stress in the upper half of the elastic range and until the proof load has been reached is not to be greater than 10 N/(mm<sup>2</sup> sec) (1 kgf/(mm<sup>2</sup> sec)). After reaching the proof load the rate of straining may be increased to a maximum of 40 per cent of the original gauge length per minute for the determination of the tensile strength.

(d) The results of all tensile tests are to comply with the values given in Table P 12.3.

(e) Where the tensile test piece representative of a batch fails to meet the test requirements and the Surveyor considers the results obtained from the fractured test piece do not fairly represent the quality of the batch, two further tensile test pieces are to be taken. These additional tests are to be prepared from material adjacent to the original test. In such cases the quality of the batch is to be judged by the result of the re-tests and not by the original test which failed.

When a test covering a batch of material fails and one or both of the re-tests also fail then the item or piece from which the tests were prepared is to be rejected. At the

TABLE P 12.2

CROSS-SECTION	GAUGE LENGTH	MINIMUM PARALLEL LENGTH
Square or Rectangular	$5,65\sqrt{S_0}$ or 50 mm	$7,15\sqrt{S_0}$ $50+1,5\sqrt{S_0}$ mm
Circular	$5d$ or 50 mm	$5,5d$ $50 + \frac{d}{2}$ mm

$S_0$  = cross-sectional area of test piece,

$d$  = diameter of test piece.



TABLE P 12.3

GRADE		GRADE AL 1	GRADE AL 2
0,2% Proof Stress	N/mm <sup>2</sup> minimum	125	195
Tensile Strength	N/mm <sup>2</sup> „	260	260
Elongation (on 5,65√S <sub>0</sub> )	per cent minimum	11	8
(on 50 mm )	per cent „	12	8

discretion of the Surveyor further tensile test pieces may be selected from at least two pieces of the remaining material in the batch for testing in accordance with the specified requirements.

Where material is tested in the heat treated condition and fails test, the whole of the material represented by the test piece may be re-heat treated and re-submitted for test provided that the material is not solution heat treated more than three times, i.e. original and two re-treatments.

#### Inspection

**1207** (a) The manufacturer shall afford the Surveyors all necessary facilities and access to all relevant parts of the works to enable them to verify that the approved method of manufacture is adhered to, for the selection of the test material, the witnessing of tests and the examination of material as required by the Rules.

(b) Surface inspection and verification of dimensions are the responsibility of the manufacturer, and acceptance by the Surveyors of material later found to be defective shall not absolve the manufacturer from this responsibility.

(c) Materials are to be free from defects of such a nature as would be harmful in service. The surface finish is to be in accordance with good practice and surfaces are not to be treated in any way that may invalidate the surface examination.

Where there is visible evidence to doubt the soundness of any material, such as flaws in test pieces or suspicious surface marks, the Surveyor may require the manufacturer to prove the material by a suitable method.

(d) In the event of any material proving unsatisfactory during subsequent working, machining or fabricating, due to faults in manufacture, such material is to be rejected notwithstanding any previous certification, and such tests of further material from the same cast may be made as the Surveyor may consider desirable.

#### Repair of Defective Material

**1208** Slight surface imperfections may be removed by

mechanical means, provided the prior agreement of the Surveyor is obtained, the work is carried out to his satisfaction and the final dimensions are acceptable.


The repair of defects by welding is not permitted.

#### Identification

**1209** (a) The manufacturer is to adopt a system of identification which will ensure that all finished material in a batch presented for test has been produced in the same way and is of the same nominal chemical composition.

The Surveyors are to be given full facilities to confirm the identification of material when required.

(b) Before any item is finally accepted, it is to be clearly marked by the manufacturer in at least one place with the following particulars:—

- (i) The Society's brand 
- (ii) The manufacturer's name or trade mark.
- (iii) Identification mark for the grade of alloy.
- (iv) Identification mark which will enable the full history of the item to be traced.
- (v) Purchaser's identification mark if required by the purchaser.

Hard stamping is to be used except when this may be detrimental to the material, when stencilling, painting or electric etching may be used.

Where a number of identical items are securely fastened together in bundles, subject to the agreement of the Surveyor, the manufacturer may brand only the top piece of each bundle, or alternatively, a durable label giving the required particulars may be attached to each bundle.

(c) When material is marked with the Society's brand prior to completion of mechanical tests and is subsequently rejected, the Surveyor is to ensure that all these marks are effectively defaced.



**Documentation**

1210 (a) The Surveyor shall be supplied with at least two copies of the mill sheets or shipping statements of all accepted material and these documents should be separate for each grade of aluminium alloy. The documents should contain, in addition to the description, dimensions, etc., of the material, the following particulars:—

- (i) Purchaser's name.
- (ii) Manufacturer's name.
- (iii) Identification mark which will enable the full history of the item to be traced.
- (iv) Identification of grade of alloy.
- (v) Chemical composition.
- (vi) Details of heat treatment (where applicable).
- (vii) Order or ship number for which intended.

(b) Before the mill sheets or shipping statements are signed by the Surveyor, the manufacturer is required to furnish him with a certificate stating that the material has been made in accordance with the requirements of this Section and that it has been subjected to, and has withstood satisfactorily, the required tests in the presence of the Surveyor or his authorized deputy. The following form of certificate will be accepted if stamped or printed on each mill sheet with the name of the works and initialled for the manufacturers by an authorized official:—

"We hereby certify that the material herein described has been made in accordance with the Rules of Lloyd's Register of Shipping for Grade..... aluminium alloy, and is that which has been tested in the presence of the Society's representative with satisfactory results."

(c) Where the alloy is not produced at the works at which it is wrought, a certificate is to be supplied to the

Surveyor at the fabricating plant stating the name of the manufacturer, the cast number, identification and the chemical composition. The works at which the alloy was produced must be approved by the Committee.

**Section 13****ALUMINIUM ALLOY RIVETS**

1301 Aluminium alloy rivets intended for use in hull construction are to be manufactured and tested in accordance with P 12 except as undernoted.

**Chemical Composition**

1302 The chemical composition of bars used for the manufacture of rivets is to comply with the requirements of Table P 13.1.

**Bar Material**

1303 (a) All bar material intended for the manufacture of rivets is to be tested.

(b) Material of the same diameter, produced in the same way and of the same chemical composition, shall be grouped into batches not exceeding 250 kg in weight. At least one test sample is to be taken from a coil or length from each batch and is to be suitably heat treated prior to the preparation of mechanical test pieces. Test samples from Grade AL 3 alloy are to be annealed and from Grade AL 4 alloy solution treated.

(c) One tensile and one dump test piece are to be prepared from each test sample.

(d) The results of all tensile tests are to comply with the values given in Table P 13.2.

**TABLE P 13.1**

GRADE	GRADE AL 3	GRADE AL 4
Copper	0,10% max.	0,10% max.
Magnesium	3,0-3,9%	0,4-1,4%
Silicon	0,5% max.	0,6-1,6%
Iron	0,5% max.	0,5% max.
Manganese	0,6% max.	0,2-1,0%
Zinc	0,2% max.	0,2% max.
Chromium	0,35% max.	0,35% max.
Titanium and other grain refining elements	0,2% max.	0,2% max.
Aluminium	The remainder	The remainder

TABLE P 13.2

GRADE	0,2% PROOF STRESS MINIMUM N/mm <sup>2</sup>	TENSILE STRENGTH MINIMUM N/mm <sup>2</sup>	MINIMUM PERCENTAGE ELONGATION	
			On $5,65\sqrt{S_0}$	On 50 mm
AL 3	90	220	18	16
AL 4	120	190	16	14

(e) Test pieces of a length and diameter equal to the full diameter of the bars shall, when cold, withstand being compressed without cracking until the diameter is increased to 1,6 times the original diameter.

#### Manufactured Rivets

**1304** (a) Rivets manufactured of the Grade AL 3 alloy are to be supplied in the annealed condition while rivets of Grade AL 4 alloy are to be supplied in the solution treated condition.

(b) From each consignment of manufactured rivets, at least three samples are to be selected for the dump test as described in 1303 (e).

#### Section 14

##### WELDING OF ALUMINIUM ALLOYS

**1401** For general requirements where welding is employed, see D 3221.

**1402** Grade AL 1 aluminium alloys are to be welded by the metal inert gas or tungsten inert gas processes. Where it is proposed to use other welding processes, details are to be submitted for approval.

Grade AL 2 aluminium alloys are not generally suitable for welded construction.

**1403** The chemical composition of filler wire used in welding is to conform to the following requirements:—

Copper	...	...	...	0,10 per cent max.
Magnesium	...	...	...	4,5 – 5,5 per cent
Silicon	...	...	...	0,6 per cent max.
Iron	...	...	...	0,5 „ „ „
Manganese	...	...	...	1,0 „ „ „
Zinc	...	...	...	0,2 „ „ „
Chromium	...	...	...	0,4 „ „ „
Titanium and other grain refining elements				
	...	...	...	0,2 „ „ „
Aluminium	...	...	...	The remainder.



## Chapter Q

# MATERIALS FOR BOILER, PRESSURE VESSEL AND MACHINERY CONSTRUCTION

### General

Materials used in the construction of boilers, pressure vessels and machinery are to be manufactured and tested in accordance with the requirements contained in the following Sections of this Chapter:—

- Section 1. General requirements for Steel Plates, Sections, Bars, Castings, Forgings, Tubes and Pipes,
- „ 2. Dimensions of test pieces and methods of test,
- „ 3. Rolled steel plates,
- „ 4. Rolled steel sections and bars,
- „ 5. Steel castings,
- „ 6. Steel forgings,
- „ 7. Steel tubes and pipes,
- „ 8. Cast iron crankshafts,
- „ 9. Copper alloy propellers and propeller blades.

With a few exceptions, the mechanical properties specified are in SI units only, but alternative units may be used for acceptance testing. In such cases, the specified values are to be converted in accordance with the appropriate Table included in “Appendix 1—Conversion Tables for use with Chapters P and Q”, following this Chapter.

### Section 1

#### GENERAL REQUIREMENTS

##### Scope

101 (a) General requirements for Steel Plates, Sections, Bars, Castings, Forgings, Tubes and Pipes intended for use in the construction of boilers, pressure vessels and machinery.

These items are to be manufactured and tested in accordance with the requirements given in this Section and Q 2, together with the specific requirements contained in the relevant Sections Q 3 to Q 7.

##### Approval of Works

(b) Steel is to be manufactured at works approved by the Committee. A list of approved manufacturers is given in Appendix 2 following this Chapter.

### Orders for Materials

(c) The order is to specify the required grade and condition of the material and the purpose for which it is intended.

Where material is required to have guaranteed properties at low or high temperature, the reference temperature for testing purposes is to be stated. This reference temperature is generally to be selected from those tabulated in the Sections giving specific requirements.

### Manufacture

102 (a) Steel is to be manufactured by the open-hearth, electric furnace or oxygen processes or by other processes approved by the Committee. An oxygen process is defined as a process in which molten iron contained in a basic lined converter is refined by directing a jet of high purity gaseous oxygen on to the surface of the hot metal.

The steel-making practice is to be such as to minimize the included non-metallic content of the finished steel. Acceptable deoxidation practices are given under the specific requirements in subsequent Sections of this Chapter.

(b) The steel is to be cast in metal ingot moulds or by an approved continuous casting process. The size of the ingot or of the continuous cast billet or slab is to be proportional to the dimensions of the final product in order that the amount of mechanical work will be adequate to ensure a satisfactory steel structure in the finished product. Provision is also to be made for sufficient discard to be taken from the top and bottom of each ingot to ensure soundness in the portion used for further processing. Periodically, and at the Surveyor's discretion, sulphur prints or other suitable proving tests may be required to demonstrate that this has been fulfilled.

(c) For certain important components it is required that the method of manufacture, or processing, be specially approved. When this condition applies, it is stated in the relevant specific requirements, and all necessary details are to be submitted for approval before production commences.



**Chemical Analysis**

103 The chemical composition is to be determined by the makers in an adequately equipped and competently staffed laboratory on samples taken from each ladle of each cast. The maker's analysis will be accepted but may be subject to occasional checks if required by the Surveyors.

**Heat Treatment**

104 All materials are to be supplied in the condition specified, or permitted, in the relevant Sections of this Chapter. Acceptable heat treatment processes and temperatures are detailed in the specific requirements. Where it is proposed to use a controlled rolling procedure, full details are to be submitted for approval.

Items normally supplied in the "as rolled" or "as drawn" condition may be subjected to a heat treatment proposed by the manufacturer for the purpose of obtaining the specified test results. Where material is supplied in the "as rolled" condition for subsequent re-working, e.g. plates for hot forming, billets for re-forging, etc., the manufacturer is to carry out any heat treatment which may be necessary to prevent hydrogen cracking or to make the material in a safe condition for transit. The proposed heat treatment is to be agreed by the Surveyor.

Heat treatment is to be carried out in properly constructed furnaces which are efficiently maintained and have adequate means for temperature control and are fitted with pyrometers which measure the temperature of the furnace charge. The furnace dimensions must permit the whole item being uniformly heated to the necessary temperature. In the case of very large structures which require heat treatment, alternative methods will be specially considered.

**Test Material**

105 (a) Sufficient test material is to be provided for the preparation of the tests detailed in the specific requirements. It is, however, in the interests of manufacturers to provide additional material for any re-tests which may be necessary, as insufficient or unacceptable test material may be a cause for rejection.

The test material is to be representative of the item, piece or batch. Cold straightening of test material may be carried out when permitted in the specific requirements, but otherwise the material is not to be re-worked or mechanically treated in any way which may influence the properties. Generally, test material is not to be removed from the item or piece until all heat treatment has been completed, except where an alternative procedure has been specially approved or where provision is made in the specific requirements for a simulated stress relieving, or blank carburizing heat treatment.

All test material is to be selected and identified by the Surveyor or an authorized deputy. These identification marks are to be maintained during the preparation of the test pieces. Dimensions of test pieces are to be in accordance with Q 2.

**Definitions**

(b) *Piece or rolled length* in respect of plates, bars and sections, is the rolled product from a single slab, bloom or ingot if this is rolled directly into plates, bars or sections.

*Item* is a single plate, bar, section or component as delivered.

*Test material or test block* is the material from which the test piece is prepared.

*Test piece* is the portion of the test material or test block on which the actual test is carried out.

**Mechanical Tests**

106 (a) All prescribed mechanical tests are to be carried out by the manufacturer before the material is despatched and unless otherwise agreed they are to be witnessed by the Surveyor.

Test methods are to be in accordance with the procedures detailed in Q 2 and the results of all tests are to comply with the specific requirements given in subsequent sections.

The tests are to be carried out by competent personnel on machines of approved types. The machines are to be maintained in a satisfactory and accurate condition and are to be re-calibrated at approximately annual intervals. This calibration is to be carried out by a nationally recognized authority or other organization of standing and is to be to the satisfaction of the Surveyor. A record of all calibrations is to be kept available in the test house.

**Re-tests**

(b) Where either the tensile test or the bend test, or both, fail and the Surveyor considers the fractured test piece or test pieces, or the results obtained therefrom, do not fairly represent the quality of the item or batch, two further test pieces of the same type are to be taken for each original test that failed. These additional tests are to be prepared from material adjacent to the original tests. In such cases the quality of the item or batch is to be judged by the result of the re-tests and not by the original test or tests which failed.

When a test covering a batch of material fails and one, or both, of the re-tests fail then the item or piece from which the tests were prepared is to be rejected. At the discretion of the Surveyor further pieces of the same type may be selected from the remaining material in the batch for testing in accordance with the specified requirements.



In the event of failure to meet impact test requirements, additional tests will only be permitted provided the average result was not less than 85 per cent of the required value. These additional tests are to consist of either three Charpy U- or V-notch test pieces or one Izod test piece, as appropriate, cut from material adjacent to the original tests. The results are to be added to the original results and the material is acceptable if the new average value complies with the specified minimum average value.

#### *Re-heat Treatment*

(c) At the option of the manufacturer, when material which is intended to be supplied in the "as rolled" or "as drawn" condition fails test, it may be heat treated and re-submitted for test. The heat treatment may be either normalizing, normalizing and tempering, or as otherwise specially agreed.

When material is tested in the heat treated condition and fails test, it may be tempered or re-tempered and re-submitted for test. It may also be re-heated for normalizing or quenching, provided it is not heated above the upper critical temperature more than three times, i.e. original and two re-treatments.

Alternatively, material which has failed test may be re-submitted as another grade.

#### *Inspection*

107 (a) The manufacturers shall afford the Surveyors all necessary facilities and access to all relevant parts of the works to enable them to verify that the approved process is adhered to, for the selection of test material, the witnessing of tests and the examination of material as required by the Rules.

(b) Surface inspection, verification of dimensions and, where appropriate, non-destructive examination are the responsibility of the manufacturer and are to be carried out on all material prior to despatch.

Witnessing of these tests by the Surveyor will be at his discretion except where this is included in the specific requirements or where specially requested by the purchaser.

Materials are to be free from segregations, flaws and laminations of such a nature as would be harmful in service. The surface finish is to be in accordance with good practice and surfaces are not to be hammered, peened or treated in any way that may invalidate the surface examination.

Slight surface imperfections may be removed by mechanical means, provided that after such treatment the dimensions are acceptable and the rectification has been completed to the satisfaction of the Surveyor.

When there is visible evidence to doubt the soundness of any material or component, such as flaws in test pieces or

suspicious surface marks, the manufacturer is expected to prove the material by any suitable method.

In the event of any material proving unsatisfactory during subsequent working, machining or fabricating, such material is to be rejected notwithstanding any previous certification.

#### *Non-destructive Testing*

(c) The techniques employed are to be in accordance with recognized good practice, including any necessary surface preparation and are to be carried out by competent personnel using reliable and efficiently maintained equipment. The term "magnetic particle examination" is intended to imply inspection for surface flaws using suitable magnetic methods, but when this is not practicable a suitable dye penetrant method may be used instead.

#### *Repair of Defective Material*


108 The repair of defects by welding is not acceptable unless the agreement of the Surveyor is obtained before the work is commenced. Repair by welding cannot be considered unless it is permitted by the specific requirements of the relevant Section in this Chapter. When a repair has been agreed it is necessary in all cases to prove by suitable methods of inspection that the defects have been completely removed before welding is commenced. Welding procedures, including pre-heating, post-weld heat treatment and inspection are to be to the complete satisfaction of the Surveyor. In all cases, the area is to be magnetic particle tested on completion of welding, heat treatment and surface grinding.

#### *Identification of Material*

109 (a) The manufacturer is to adopt a system of identification which will enable all finished material to be traced to the original cast and the Surveyors are to be given full facilities for so tracing the material when required. When any item has been identified by the personal mark of a Surveyor, or his deputy, this is not to be removed until an acceptable new mark has been made. Failure to comply with this condition will render the item liable to rejection.

(b) Before any item is finally accepted it is to be clearly marked by the manufacturer in at least one place. The following particulars are to be shown:—

#### *Plates, Bars and Sections*

- (i) The Society's brand 
- (ii) The manufacturer's name or trade mark.
- (iii) Identification mark for the grade of steel.
- (iv) Identification mark which will enable the full history of the item to be traced.
- (v) Purchaser's identification mark if required by the purchaser.



*Castings, Forgings, Tubes and Pipes*

- (i) "L.R." or "Lloyd's" and the abbreviated name of the Society's local office.
- (ii) Identification mark which will enable the full history of the item to be traced.
- (iii) Date of final inspection.
- (iv) Personal stamp of Surveyor responsible for the final inspection.

Hard stamping is to be used except when this may be detrimental to the material, when stencilling, painting or electric etching may be used. Paints used for identifying alloy steels are to be free from lead, copper, zinc or tin.

Where a number of identical items are securely fastened together in bundles, subject to the agreement of the Surveyor the manufacturer may brand only the top piece of each bundle, or alternatively, a durable label giving the required particulars may be attached to each bundle.

- (c) When material is marked with the Society's brand

**R**, "L.R.," "Lloyds" or the personal stamp of the Surveyor prior to completion of mechanical tests and is subsequently rejected, the Surveyor is to ensure that all these marks are effectively defaced.

**Documentation**

110 The manufacturer is to provide the Surveyor with a written statement giving the steelmaking process, cast number, cast analysis, mechanical test results and general details of heat treatment used for each item together with full particulars of the purchaser, order number and description.

When steel is not produced at the works at which it is rolled or forged, a certificate is to be supplied to the Surveyor at the rolling mill, forge or tube mill stating the process by which the steel was manufactured, the name of the steel-maker, the cast number, identification and ladle analysis. The works at which the steel was produced must be approved by the Committee.

**Section 2****DIMENSIONS OF TEST PIECES AND METHODS OF TEST****Tensile Test Pieces**

201 (a) Proportional test pieces for tensile tests with a gauge length of  $5,65\sqrt{S_0}$ , where  $S_0$  is the cross-sectional area of the test length, have been adopted as the standard form of test piece and in subsequent Sections of this Chapter, the minimum percentage elongation values are given for

test pieces of these proportions. For reference purposes the test piece is to be machined to a diameter of 14 mm with a gauge length of 70 mm. The minimum length of the parallel test length is to be 80 mm and the ends may be machined in a form suitable for the grips of the testing machine provided there is an adequate radius between the test length and the enlarged ends.

(b) For routine testing purposes round machined test pieces with other diameters and gauge lengths may be used, subject to any requirements for minimum diameter or cross-sectional area given in subsequent Sections. Any of the test pieces detailed below may also be used for routine testing purposes. In all cases where the gauge length used is other than  $5,65\sqrt{S_0}$  the equivalent percentage elongation is to be calculated using the formulæ or Tables given in 202.

**Square or Rectangular Non-proportional Tensile Test Pieces**

(c) These are to be machined to a minimum width of 25 mm and are to be the full thickness of the material with the rolled surfaces retained. The gauge length is to be 200 mm and the minimum length of the parallel section is to be 225 mm. For rectangular sections the ratio of the sides is not to exceed 4 to 1. The ends may be machined to a greater width to suit the grips of the testing machine, provided there is an adequate radius between the test length and enlarged ends.

**Full-section Tensile Test Pieces**

(d) Test samples from bars and other small rolled sections may be tested in full section. The cross-sectional area is to be calculated either from accurate measurement of the average dimensions or by determining the weight of a known length.

**Tensile Pieces from Tubes and Pipes**

(e) Samples from tubes and pipes may be tested in full section as above, provided the ends are plugged and the length of the test piece between the grips is at least 50 mm greater than the gauge length.

Alternatively, test pieces may be prepared from strips cut longitudinally from the tubes or pipes. These test pieces are to be machined to a minimum width of 12 mm but the ends may be machined to a greater width to suit the grips of the machine, provided there is an adequate radius between the test length and the enlarged ends. The central test length is not to be flattened but the enlarged ends may be flattened for gripping in the testing machine. The gauge length is to be 50 mm and the minimum length of the parallel portion is to be 60 mm.



The cross-sectional area of this type of test piece having parallel edges is to be calculated as follows:—

$$S_0 = a b$$

where  $S_0$  = cross-sectional area,

$a$  = average radial thickness,

$b$  = average width.

For thick walled pipes, the test material may be cut in either a longitudinal or circumferential direction and machined round test pieces prepared.

### Equivalent Elongation

202 When a gauge length other than  $5,65\sqrt{S_0}$  is used, the equivalent percentage elongation value is to be calculated using the following formula:—

$$E = \frac{n}{2} \left[ \frac{L_0}{\sqrt{S_0}} \right]^{0,40}$$

where  $n$  = actual measured percentage elongation of test piece,

$S_0$  = actual cross-sectional area of test piece,

$L_0$  = actual gauge length of test piece,

$E$  = equivalent percentage elongation for a test piece with a gauge length of  $5,65\sqrt{S_0}$

Alternatively, where a number of test pieces of similar material and dimensions are involved the actual percentage elongation values may be recorded, provided the equivalent specified minimum elongation value appropriate for the test piece dimensions is calculated from the above formula and is recorded on the test sheet.

For proportional test pieces having a gauge length other than  $5,65\sqrt{S_0}$  the equivalent elongation may be calculated using the following factors:—

Actual gauge length	Factor for equivalent elongation on $5,65\sqrt{S_0}$
$4\sqrt{S_0}$	$\times 0,870$
$8,16\sqrt{S_0}$	$\times 1,158$
$11,3\sqrt{S_0}$	$\times 1,317$
$4d$	$\times 0,916$
$8d$	$\times 1,207$

For non-proportional test pieces with gauge lengths of 50 mm and 200 mm the equivalent elongation may be determined from Tables Q 2.1 and Q 2.2.

The above conversions are only reliable for carbon and carbon-manganese steels with a tensile strength not exceeding 690 N/mm<sup>2</sup> in the hot rolled, annealed, normalized or normalized and tempered conditions.

For alloy steels in the oil hardened and tempered condition, the following conversion may be used for proportional test pieces with a gauge length of  $4\sqrt{S_0}$ .

Actual percentage elongation on $4\sqrt{S_0}$	Equivalent elongation on $5,65\sqrt{S_0}$
22	17
20	15
18	13
17	12
16	12
15	11
14	10
12	8
10	7
8	5

For the following materials, the acceptance of any proposed conversion factor is to be at the discretion of the Surveyor:—

- Carbon and carbon-manganese steels with a tensile strength exceeding 690 N/mm<sup>2</sup>,
- Alloy steels in the normalized or normalized and tempered condition,
- Cold worked steels,
- Austenitic steels,
- Non-ferrous alloys.

### Discarding of Tensile Test Pieces

203 Where the specified minimum percentage elongation is not obtained, and the distance between the fracture and nearer gauge mark is less than a third of the original gauge length, the test piece is to be discarded. A further test piece is to be prepared and the quality of the material is to be judged entirely on the results obtained from this additional test.

### Tensile Tests at Ambient Temperature

204 (a) The yield phenomena is not exhibited by all the materials specified in subsequent Sections of this Chapter but, for simplification, reference is only made to yield stress. Where no distinct yield is observed this is to be interpreted as either the 0,2 per cent proof stress or the 0,5 per cent proof stress under load.

(b) The yield stress is to be calculated from either:—

*Beam Machines.* The load immediately prior to a distinct drop in the testing machine lever,

*Indicating Machines.* The load immediately prior to a fall back in the movement of the pointer or the load at a marked hesitation of the pointer.

(c) The 0,2 per cent proof stress is to be determined from an accurate load/extension diagram by drawing a line parallel to the straight elastic portion and distant from it by an amount representing 0,2 per cent of the extensometer gauge

TABLE Q 2.1

EQUIVALENT ELONGATION ON  $5,65\sqrt{S_0}$  FOR TEST PIECES WITH GAUGE LENGTHS OF 50 mm

ACTUAL PERCENTAGE ELONGATION ON 50 mm GAUGE LENGTH	CORRESPONDING PERCENTAGE ELONGATION ON $5,65\sqrt{S_0}$ GAUGE LENGTH WHERE CROSS-SECTIONAL AREA in mm <sup>2</sup> IS:—											
	50	100	150	200	300	400	500	600	700	800	900	1000
18	20	17	16	15	14	13	12	12	12	11	11	11
19	21	18	17	16	15	14	13	13	12	12	12	11
20	22	19	18	17	15	14	14	13	13	13	12	12
21	23	20	19	18	16	15	15	14	14	13	13	13
22	24	21	20	18	17	16	15	15	14	14	14	13
23	25	22	20	19	18	16	16	15	15	15	14	14
24	26	23	21	20	18	17	17	16	16	15	15	15
25	27	24	22	21	19	18	17	17	16	16	15	15
26	28	25	23	22	20	19	18	17	17	16	16	16
27	29	26	24	23	21	20	19	18	18	17	17	16
28	31	27	25	23	22	20	19	19	18	18	17	17
29	32	28	26	24	22	21	20	19	19	18	18	18
30	33	29	27	25	23	22	21	20	19	19	19	18
31	34	30	27	26	24	23	21	21	20	20	19	19
32	35	31	28	27	25	23	22	21	21	20	20	19
33	36	32	29	28	25	24	23	22	21	21	20	20
34	37	33	30	28	26	25	24	23	22	22	21	21
35	38	33	31	29	27	25	24	23	23	22	22	21
36	39	34	32	30	28	26	25	24	23	23	22	22
37	40	35	33	31	28	27	26	25	24	23	23	22
38	42	36	34	32	29	28	26	25	25	24	23	23
39	43	37	35	33	30	28	27	26	25	25	24	24
40	44	38	35	33	31	29	28	27	26	25	25	24
41	45	39	36	34	32	30	28	27	27	26	25	25
42	46	40	37	35	32	30	29	28	27	27	26	25
43	47	41	38	36	33	31	30	29	28	27	27	26
44	48	42	39	37	34	32	30	29	28	28	27	27
45	49	43	40	38	35	33	31	30	29	28	28	27
46	50	44	41	38	35	33	32	31	30	29	28	28
47	51	45	42	39	36	34	33	31	30	30	29	28



TABLE Q 2.2

EQUIVALENT ELONGATION ON  $5,65\sqrt{S_0}$  FOR TEST PIECES WITH GAUGE LENGTHS OF 200 mm

ACTUAL PERCENTAGE ELONGATION ON 200 mm GAUGE LENGTH	CORRESPONDING PERCENTAGE ELONGATION ON $5,65\sqrt{S_0}$ GAUGE LENGTH WHERE CROSS-SECTIONAL AREA in mm <sup>2</sup> IS:—														
	100	150	200	300	400	500	600	700	800	900	1000	1500	2000	2500	3000
10	17	15	14	13	13	12	11	11	11	11	10	10	9	9	8
11	18	17	16	15	14	13	13	12	12	12	11	11	10	10	9
12	20	18	17	16	15	14	14	13	13	13	13	12	11	10	10
13	22	20	19	17	16	16	15	15	14	14	14	13	12	11	11
14	24	21	20	19	18	17	16	16	15	15	15	14	13	12	12
15	25	23	22	20	19	18	17	17	16	16	16	15	14	13	13
16	27	25	23	21	20	19	18	18	18	17	17	16	15	14	14
17	29	26	25	23	21	20	20	19	19	18	18	17	16	15	14
18	30	28	26	24	23	22	21	20	20	19	19	18	17	16	15
19	32	29	27	25	24	23	22	21	21	20	20	18	17	17	16
20	34	31	29	27	25	24	23	23	22	21	21	19	18	18	17
21	35	32	30	28	27	25	24	24	23	23	22	20	19	18	18
22	37	34	32	29	28	27	26	25	24	24	23	21	20	19	19
23	39	35	33	31	29	28	27	26	25	25	24	22	21	20	20
24	40	37	35	32	30	29	28	27	26	26	25	23	22	21	20
25	42	38	36	33	32	30	29	28	28	27	26	24	23	22	21
26	44	40	38	35	33	31	30	29	29	28	27	25	24	23	22
27	45	41	39	36	34	33	31	30	30	29	28	26	25	24	23
28	47	43	41	38	35	34	33	32	31	30	29	27	26	25	24
29	49	45	42	39	37	35	34	33	32	31	30	28	27	25	25
30	50	46	43	40	38	36	35	34	33	32	31	29	28	26	25
31	52	48	45	41	39	37	36	35	34	33	33	30	28	27	26
32		49	46	43	40	39	37	36	35	34	34	31	29	28	27
33		51	48	44	42	40	38	37	36	35	35	32	30	29	28
34		52	49	46	43	41	40	38	37	36	36	33	31	30	29
35			51	47	44	42	41	40	38	38	37	34	32	31	30
36			52	48	45	43	42	41	40	39	38	35	33	32	31
37				50	47	45	43	42	41	40	39	36	34	32	31
38				51	48	46	44	43	42	41	40	37	35	33	32
39				52	49	47	45	44	43	42	41	38	36	34	33



length. The point of intersection of this line with the plastic portion of the diagram represents the proof load, from which the 0,2 per cent proof stress can be calculated.

(d) The 0,5 per cent proof stress under load is to be calculated from the load corresponding to a *total* extension of 0,5 per cent of the original gauge length. This extension is to be measured either by the use of a suitable extensometer or by dividers.

(e) In all cases the rate of increase of stress in the upper half of the elastic range and until the yield load has been reached is not to be greater than 10 N/(mm<sup>2</sup> sec) (1 kgf/(mm<sup>2</sup> sec)). After reaching the yield load the rate of straining may be increased to a maximum of 40 per cent of the original gauge length per minute for the determination of the tensile strength.

#### Tensile Tests at Elevated Temperatures

205 Test pieces used for the determination of lower yield or 0,2 per cent proof stress at elevated temperatures are to have an extensometer gauge length of not less than 50 mm and a cross-sectional area of not less than 65 mm<sup>2</sup>. Where, however, the dimensions of the product or the test equipment available will not permit this size of test piece being used, the test piece is to be of the largest practicable dimensions.

For materials which show the yield phenomenon, the straining rate in the upper half of the elastic range and during determination of the lower yield stress is to be within the range of 0,1 per cent to 0,3 per cent of the gauge length per minute and should preferably be controlled by reference to a strain pacer or a strain rate meter with a time interval between measurements of strain not exceeding 6 seconds. As an alternative to the use of a strain pacer or a strain rate meter the rate of increase of stress in the elastic range equivalent to the above maximum straining rate may be calculated taking into account the characteristics of the testing machine, the cross-section and gauge length of the test piece. This calculated value can then be used to control the straining rate during testing.

When the 0,2 per cent proof stress is being determined the rate of increase of stress in the upper half of the elastic range and during determination of the proof stress is not to exceed 40 N/(mm<sup>2</sup> min) (4 kgf/(mm<sup>2</sup> min)).

#### Bend Test Pieces

206 Test pieces for bend tests are to be sheared or machined to the following dimensions:—

Plates and Sections: Plate or section thickness with a minimum width of 35 mm. The rolled surfaces are to be retained.

Thick Plates: When the power of the available testing machine is insufficient to bend a test piece of the full thickness, two test pieces each 25 mm thick by 35 mm wide are to be machined. One rolled surface is to be retained on each test piece and this is to be the side tested in tension.

Forgings and Castings: To be machined to a rectangular section 25 mm wide by 20 mm thick. A subsidiary test piece 20 mm wide by 10 mm thick is permitted for higher tensile strength steel and tests from rotor forgings. For steel castings a test piece machined to 25 mm diameter may also be used.

Rolled Bars: Bars up to and including 25 mm diameter are to be tested in full section. For larger diameter bars either a round test piece 25 mm diameter or a rectangular test piece 25 mm wide by 20 mm thick is to be machined.

Pipes: The bend test piece is to be cut as a circumferential strip of the full wall thickness and with a width of not less than 35 mm. For thick walled pipes the wall thickness may be reduced to 20 mm by machining. The test piece is to be bent in the direction of the original curvature.

The sharp edges of all rectangular section bend test pieces may be removed by suitable mechanical means to a radius not exceeding 1,5 mm.

#### Procedure for Bend Tests

207 This test is to be carried out at ambient temperature and is to consist of bending the test piece by pressure or hammer blows round a suitable former. The diameter of the former and the required angle of bend are to be in accordance with the specific requirements for the material. When an angle of bend of 180° is required, the sides after bending are to be parallel and apart by a distance equal to the diameter of the former specified for the material.

The test is considered to be satisfactory if, after bending as above, the test piece is unbroken and free from cracks and in the case of rolled products is also free from laminations. Small cracks at the edges of rectangular test pieces are to be disregarded.

#### Impact Tests

208 Test pieces for impact tests are to be either of the Charpy V-notch, Charpy U-notch or Izod types as required in subsequent Sections giving specific requirements for different components and materials.

The test pieces are to be machined to the dimensions and tolerances given in Tables Q 2.3 and Q 2.4.



TABLE Q 2.3

## OVERALL DIMENSIONS AND TOLERANCES FOR IMPACT TEST PIECES

DESIGNATION	NOMINAL DIMENSION	TOLERANCE
CHARPY V-NOTCH AND U-NOTCH		
Length ... ..	55 mm	$\pm 0,60$ mm
Width Standard ... ..	10 mm	$\pm 0,11$ mm
Subsidiary Standard ... ..	7,5 mm	$\pm 0,11$ mm
" " ... ..	5,0 mm	$\pm 0,05$ mm
" " ... ..	2,5 mm	$\pm 0,05$ mm
Thickness ... ..	10 mm	$\pm 0,11$ mm
Distance of notch from end of test piece ...	27,5 mm	$\pm 0,42$ mm
SQUARE IZOD		
Length Standard 3 notch ... ..	130 mm	minimum
2 notch ... ..	100 mm	minimum
1 notch ... ..	75 mm	minimum
Width ... ..	10 mm	$\pm 0,11$ mm
Thickness ... ..	10 mm	$\pm 0,11$ mm
Distance of notch from end of test piece and from adjacent notch ... ..	28 mm	$\pm 0,42$ mm
ROUND IZOD		
Length Standard 3 notch ... ..	132 mm	minimum
2 notch ... ..	104 mm	minimum
1 notch ... ..	76 mm	minimum
Diameter ... ..	11,43 mm	$\pm 0,14$ mm
Distance of notch from end of test piece and from adjacent notch ... ..	27,94 mm	$\pm 0,42$ mm

TABLE Q 2.4

## DIMENSIONS AND TOLERANCES OF NOTCH FOR ALL TYPES OF IMPACT TEST PIECES

DESIGNATION	CHARPY V-NOTCH AND IZOD		CHARPY U-NOTCH	
	NOMINAL DIMENSION	TOLERANCE	NOMINAL DIMENSION	TOLERANCE
Angle of notch ... ..	45°	$\pm 2^\circ$	—	—
Depth below notch ... ..	8 mm*	$\pm 0,11$ mm*	5 mm	$\pm 0,09$ mm
Root radius ... ..	0,25 mm	$\pm 0,025$ mm	1 mm	$\pm 0,07$ mm
Angle between plane of symmetry of notch and the longitudinal axis of the test piece ... ..	90°	$\pm 2^\circ$	90°	$\pm 2^\circ$

\*For round Izod test piece 8,128 mm  $\pm$  0,045 mm

For material under 10 mm in thickness, the largest possible size of subsidiary Charpy V-notch or U-notch is to be prepared with the notch cut on the narrow face. Generally, impact tests are not required when the thickness of the material is under 3 mm.

For 2 or 3 notch square Izod test pieces only one notch is to be cut on any one face. Notches on round Izod test pieces are to be similarly orientated.

Where Charpy V-notch or U-notch test pieces are taken from rolled products the notch is to be cut on the face of the test piece which was originally perpendicular to the rolled surface.

The impact test is to consist of either 3 Charpy V-notch or U-notch test pieces or one standard 3 notch Izod test piece (or equivalent 1 or 2 notch test pieces) as may be specified.

Charpy U-notch and Izod impact tests are generally to be carried out at ambient temperature. Charpy V-notch tests may be carried out at ambient or lower temperatures in accordance with the specific requirements given in subsequent Sections. Where the test temperature is other than ambient the temperature of the test pieces is to be controlled to within  $\pm 2$  degC for a sufficient time to ensure uniformity throughout the cross-section of the test piece and suitable precautions are to be taken to prevent any significant change in temperature during the actual test. In cases of dispute, ambient temperature is to be considered as  $20 \pm 2^\circ\text{C}$ .

When reporting results the units used for expressing the energy absorbed and the actual testing temperature are to be clearly stated.

#### Flattening Test on Boiler Tubes and Pipes

209 The test piece is to consist of a piece of tube or pipe with the ends perpendicular to the axis. The length is to be equal to 1,5 times the nominal internal diameter but is to be not less than 10 mm nor more than 100 mm. Alternatively, the test may be made on the end of a tube or pipe without the test piece being removed, provided that the length flattened is as above. The cut ends of the test piece may be rounded by filing.

The test is to be carried out at ambient temperature and is to consist of flattening the test piece in a direction perpendicular to the longitudinal axis of the pipe. Flattening is to be carried out between two plain parallel and rigid platens which extend over both the full length and the width after flattening of the test piece. Flattening is to be continued until the distance between the platens, measured under load, is not greater than that given in the specific

requirements. After flattening the test piece is to be unbroken and free from cracks or other flaws. Small cracks at the ends of test pieces may be disregarded.

For electric resistance welded tubes or pipes the weld is to be placed at the line of maximum bending.

#### Drift Expanding Test on Boiler Tubes

210 The test piece is to consist of a piece of tube with one end cut perpendicular to the axis. The length is to be equal to 1,5 times the external diameter but not less than 50 mm. Alternatively, the test may be made on the end of a tube without the test piece being removed. The edges of the end to be tested may be rounded by filing.

The test is to be carried out at ambient temperature and is to consist of expanding the end of the tube symmetrically by means of a hardened conical steel mandrel having a total included angle of between  $40^\circ$  and  $60^\circ$ , see Fig. Q 2.1. The mandrel is to be forced into the test piece until the percentage increase in the external diameter of the end of the test piece reaches the value given in the specific requirements for boiler tubes. The mandrel is to be lubricated but there is to be no rotation of the tube or mandrel during the test.

The expanded portion of the tube is to be free from cracks or other flaws.

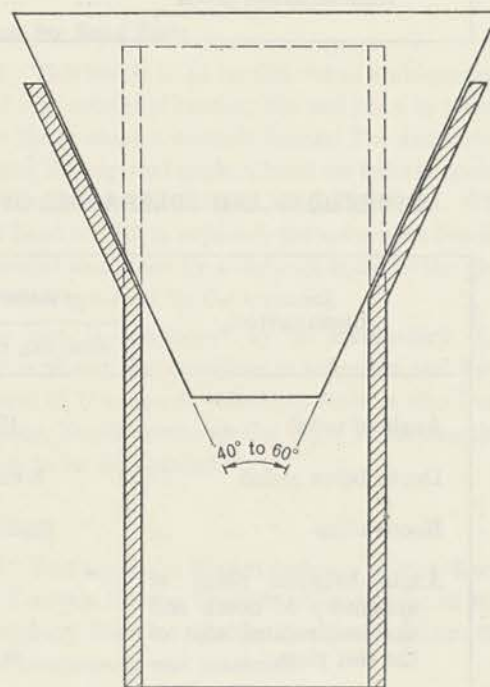


FIG. Q 2.1 DRIFT EXPANDING TEST



**Section 3****ROLLED STEEL PLATES****Scope**

301 This Section gives specific requirements for carbon, carbon-manganese and low alloy steel plates intended for use in the construction of boiler or superheater drums or headers, pressure vessels and welded machinery structures. For pressure vessels containing radioactive materials or gases, additional requirements may be specified.

The steel plates are to be manufactured and tested in accordance with the requirements of this Section and the relevant requirements of Q 1 and Q 2. Provision is made for four categories of plates which differ mainly in respect of testing procedures and are intended for the following uses:—

- Category I For boilers and pressure vessels where design is based on guaranteed values for elevated temperature properties.
- Category II(a) For boilers and pressure vessels where design is based on nominal values for elevated temperature properties which are not required to be proved by test.
- Category II(b) For welded machinery structures.
- Category III For pressure vessels intended for special low temperature service where the steel is to have guaranteed low temperature Charpy V-notch impact properties. In this case the proposed specification is to be submitted for approval.

Alternatively, steel plates complying with national or proprietary specifications may be accepted provided these specifications give reasonable equivalence to the requirements of this Section.

**Manufacture**

302 For Categories I and II the method of de-oxidation is to be in accordance with that given in Table Q 3.1. For Category III the method of de-oxidation is to be included in the specification submitted for approval. Silicon killed or aluminium treated steels are to be cast in moulds with efficient feeder heads.

**Chemical Composition**

303 For Categories I or II the chemical composition of the steel is to comply with the requirements given in Table Q 3.1. This Table also gives details of the grades for each category.

The chemical composition of steels for Category III is to comply with the approved specification.

**Heat Treatment**

304 All plates are to be supplied in the condition detailed in Table Q 3.2, unless otherwise agreed. For carbon and carbon-manganese steels an approved procedure for controlled rolling can be accepted instead of a normalizing heat treatment. Plates intended for hot forming may be supplied in the "as rolled" condition provided that they are either hot formed in the normalizing temperature range or are normalized after hot forming.

If required by the Surveyors or by the fabricator, test material may be given a simulated stress relieving heat treatment prior to the preparation of the test pieces. This has to be stated on the order together with agreed details of the simulated heat treatment and the mechanical properties which can be accepted.

**Test Material**

305 (a) Category I. Tensile tests at ambient temperature and bend tests are to be taken from one end of each rolled length when the weight is not in excess of 2,5 tonnes. When the weight exceeds 2,5 tonnes these tests are to be taken from both ends.

For applications where the design temperature is in excess of 100° C one elevated temperature tensile test is to be taken from each rolled length. When the rolled length exceeds 2,5 tonnes in weight the test piece is to be taken from the end which gave the lower tensile value at ambient temperature. These tensile tests at elevated temperatures are not required when:—

- (i) the reference test temperature is 100°C or less,
- or (ii) the specified minimum value of the 0,2 per cent proof stress value at the reference test temperature is higher than the corresponding stress-to-rupture value,
- or (iii) the actual tensile strength at ambient temperature exceeds by at least 40 N/mm<sup>2</sup> (4 kgf/mm<sup>2</sup>) the specified minimum tensile strength. This applies only to carbon and carbon-manganese steels,
- or (iv) the steelmaker has obtained certification of elevated temperature proof stress values, as detailed in 306(d).

Category II (a). Tensile tests at ambient temperature and bend tests are to be taken as for Category I. Tensile tests at elevated temperatures are not required.

Category II (b). One tensile test piece is to be taken from the thickest piece in each batch of 20 tonnes or less, from the same cast. Where the thicknesses of the pieces

**TABLE Q 3.1**  
**CHEMICAL COMPOSITION OF PLATES, CATEGORIES I and II**

GRADE OF STEEL	TENSILE STRENGTH N/mm <sup>2</sup>	CATEGORY	METHOD OF DE-OXIDATION	CHEMICAL COMPOSITION OF LADLE SAMPLES, PER CENT								
				C	Si	Mn	S	P	Residual Elements			
Carbon and Carbon- Manganese	360-460	I, II(a), II(b)	Any except rimming	0,17 max.	0,35 max.	0,40-1,20	0,050 max.	0,050 max.	Ni 0,30 max. Cr 0,25 max. Mo 0,10 max. Cu 0,30 max.  Total 0,70 max.			
	410-510	I, II(a), II(b)	Any except rimming	0,20 max.	0,35 max.	0,50-1,30	0,050 max.	0,050 max.				
	460-560	I, II(a)	Any except rimming (Note 1)	0,20 max. (Note 2)	0,35 max.	0,60-1,40	0,050 max.	0,050 max.				
	510-610	I, II(a)	Any except rimming (Note 1)	0,20 max. (Note 2)	0,50 max.	0,90-1,50	0,050 max.	0,050 max.				
Low Alloy 1Cr $\frac{1}{2}$ Mo	430-550	I	Silicon killed	C	Si	Mn	S	P	Ni	Cr	Mo	Cu
				0,18 max.	0,15-0,35	0,4-0,8	0,040 max.	0,040 max.	0,30 max.	0,8-1,2	0,4-0,6	0,20 max.
2 $\frac{1}{4}$ Cr1Mo	510-660	I	Silicon killed	0,15 max.	0,15-0,35	0,4-0,8	0,040 max.	0,040 max.	0,30 max.	2,0-2,5	0,9-1,1	0,20 max.

NOTES. 1. May also contain Niobium 0,08 per cent max.

2. For material over 30 mm in thickness Carbon 0,22 per cent max.



**TABLE Q 3.2**  
**HEAT TREATMENT OF PLATES**

GRADE OF STEEL	TENSILE STRENGTH	CATEGORY I	CATEGORIES II(a) & II(b)	CATEGORY III
	N/mm <sup>2</sup>			
Carbon and Carbon- Manganese	360-460	All thicknesses to be normalized	Plates exceeding 45 mm in thickness to be normalized	In accordance with approved specification
	410-510			
	460-560	All thicknesses to be normalized	All thicknesses to be normalized	In accordance with approved specification
	510-610			
Low Alloy 1Cr $\frac{1}{2}$ Mo	430-550	All thicknesses to be normalized ( <i>see Note</i> )		
2 $\frac{1}{4}$ Cr1Mo	510-660	All thicknesses to be normalized and tempered		

NOTE. May also be normalized and tempered

within a batch vary by more than 12 mm an additional test representing the thinner material is to be taken.

One bend test piece is to be taken from each rolled length.

Category III. Tensile tests at ambient temperature and bend tests are to be taken as for Category I and in addition a set of three Charpy V-notch test pieces is to be taken from one end of each rolled length.

(b) Test pieces for tensile tests at ambient and elevated temperatures and for bend tests are to be transverse to the principal direction of rolling and are to be cut from the plate end or ends at approximately quarter width. The axis of fully machined round proportional test pieces is, when the thickness permits, to be co-incident with the quarter thickness of the plate.

Impact test pieces are to be cut from a similar position but are to be parallel to the principal direction of rolling. They are to be machined from material close to one of the rolled surfaces.

(c) When plates are required for hot forming and it has been agreed that the heat treatment will be carried out by the fabricator then the tests at the steelworks are to be made on material which has been cut from the plates and given a normalizing or normalizing and tempering heat treatment in a manner simulating the treatment which will be applied to the plates.

(d) Cold straightening of material for tensile and impact tests is not permitted.

(e) All test pieces are to be machined in accordance with Q 2 and for tests at ambient temperature the tensile test pieces are to have a cross-sectional area of not less than 150 mm<sup>2</sup>.

#### Mechanical Properties

**306** (a) Category I. The results of all tensile tests are to comply with the values given in Table Q 3.3. The lower yield or 0.2 per cent proof stress values at elevated temperatures are to be determined at the reference test temperature given in the order (*see* Q 101(c)).

Bend test pieces are to withstand being bent through an angle of 180° round a former having a diameter not greater than that specified in Table Q 3.3.

Stress rupture values for design purposes are given in Table Q 3.5.

(b) Category II. The results of all tensile tests at ambient temperature are to comply with the values given in Table Q 3.4.

Bend test pieces are to withstand being bent through an angle of 180° round a former having a diameter not greater than that specified in Table Q 3.4.

For design purposes nominal values of the lower yield or 0.2 per cent proof stress at elevated temperatures are given in Table Q 3.4 for carbon and carbon-manganese steels. Stress rupture values are given in Table Q 3.5.

(c) Category III. The results of all the tensile, bend and impact tests are to comply with the approved specification. The Charpy V-notch tests are to be made at or below the reference test temperature given in the order (*see* Q 101(c)).

Table Q 3.3

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TABLE Q 3.3  
MECHANICAL PROPERTIES OF PLATES, CATEGORY I

GRADE OF STEEL	YIELD STRESS N/mm <sup>2</sup> MINIMUM FOR THICKNESS in mm (NOTE 1)			TENSILE STRENGTH N/mm <sup>2</sup>	ELONGATION ON $5,65\sqrt{S_0}$ % MINIMUM (NOTE 2)	BEND TEST MAXIMUM DIAMETER OF FORMER	MINIMUM LOWER YIELD OR 0,2% PROOF STRESS, N/mm <sup>2</sup> (=MPa) (NOTE 1)										
	Up to 16	Over 16 to 40	Over 40 to 63				100°C	150°C	200°C	250°C	300°C	350°C	400°C	450°C	500°C	550°C	600°C
Carbon and Carbon- Manganese	235	225	215	360-460	25	2t	172	167	162	147	132	123	113	98			
	255	245	235	410-510	23	2t	206	201	191	177	157	147	137	118			
	295	285	275	460-560	21	3t	245	235	221	201	186	172	157	137			
	355	345	335	510-610	20	3t	284	275	255	235	216	201	177	157			
Low Alloy 1Cr $\frac{1}{2}$ Mo	285	275	275	430-550	23	3t	Values by agreement with the manufacturer										
2 $\frac{1}{4}$ Cr1Mo	315	305	305	510-660	18	3t											

t = thickness of bend test piece.

NOTES. 1. These values apply only to plates up to 63 mm in thickness. For thicker plates the yield stress or the 0,2 per cent proof stress values are to be reduced by 1 per cent for each 5 mm increase in thickness over 63 mm.

2. For plates over 63 mm in thickness the minimum percentage elongation values are to be reduced by 1.



TABLE Q 3.4

## MECHANICAL PROPERTIES OF PLATES, CATEGORY II

GRADE OF STEEL	YIELD STRESS N/mm <sup>2</sup> MINIMUM FOR THICKNESS in mm			TENSILE STRENGTH N/mm <sup>2</sup>	ELONGATION ON $5,65\sqrt{S_0}$ % MINIMUM (NOTE 2)	BEND TEST MAXIMUM DIAMETER OF FORMER	LOWER YIELD OR 0,2% PROOF STRESS N/mm <sup>2</sup> (=MPa) (NOTE 1)										
	Up to 16	Over 16 to 40	Over 40 to 63				100°C	150°C	200°C	250°C	300°C	350°C	400°C	450°C	500°C	550°C	600°C
Carbon and Carbon- Manganese	205	195	185	360-460	25	2t	145	142	139	126	110	94	92	92			
	230	220	210	410-510	23	2t	177	173	170	155	139	124	121	118			
	260	250	240	460-560	21	3t	206	204	199	182	167	151	142	132			
	295	285	275	510-610	20	3t	236	233	227	210	195	179	162	147			

t = thickness of bend test piece

NOTES. 1. The values for yield stress or 0,2 per cent proof stress at elevated temperatures are given for design purposes and do not have to be proved by test.

2. For plates over 63 mm in thickness the minimum percentage elongation values are to be reduced by 1.

TABLE Q 3.5

AVERAGE VALUES FOR STRESS TO RUPTURE IN 100 000 HOURS, CATEGORIES I AND II

Units: N/mm<sup>2</sup> (=MPa)

TEMPERATURE °C	CARBON AND CARBON-MANGANESE STEEL	1Cr $\frac{1}{2}$ Mo STEEL	2 $\frac{1}{4}$ Cr 1Mo STEEL
350	211		
360	193		
370	176		
380	157		
390	140		
400	123		
410	106		
420	92		
430	81		
440	72		
450	64	314	
460	56	279	
470	49	245	
480	43	212	210
490	37	179	188
500	32	148	169
510		122	148
520		99	129
530		78	113
540		62	97
550		49	83
560		40	71
570		31	60
580		24	51
590			43
600			37



*Certification of Lower Yield or 0,2 per cent Proof Stress Values at Elevated Temperatures*

(d) For Category I material and other approved grades, as an alternative to taking tensile tests at elevated temperatures from each plate, individual steelmakers may submit for analysis and approval comprehensive test data for a specific grade of steel to demonstrate the lower yield or 0,2 per cent proof stress values at elevated temperatures which can be consistently obtained. This data will be assessed on a statistical basis to determine the 95 per cent lower confidence limits. When a manufacturer is approved on this basis routine tensile tests at elevated temperatures will not be required except for periodic check tests at the discretion of the Surveyors.

Steelmakers requiring this form of certification are to submit the following information and test data from at least 45 plates taken from not less than 10 different casts for each grade of steel.

- (1) Ladle analysis including residual elements,
- (2) Method of de-oxidation,
- (3) Details of heat treatment,
- (4) Results of tensile tests at ambient temperature:—  
Yield stress, tensile strength and percentage elongation,
- (5) Results of tensile tests at elevated temperatures:—  
Lower yield or 0,2 per cent proof stress values at 100, 150, 200, 250, 300, 350, 400, 450° C or higher if appropriate for the grade of steel being tested.
- (6) Plate thickness.

The test data are to be representative of the tensile range specified for the grade and also the range of thickness which will be manufactured. For carbon and carbon-manganese steels where there is an overlap in the specified tensile strength range, data submitted for one grade may also be considered for adjacent grades provided the ambient temperature properties comply with the appropriate tensile strength range.

#### Inspection

307 Inspection is to be carried out in accordance with Q 107.

#### Repair of Defects

308 The repair of defects by welding at the steelworks is not accepted but proposals for the repair of minor surface defects by the fabricator in accordance with Q 108 will be considered.

#### Identification

309 Plates are to be identified in accordance with Q 109.

#### Documentation

310 The manufacturer is to supply the information detailed in Q 110.

### Section 4

#### ROLLED STEEL SECTIONS AND BARS

##### Scope

401 (a) Hot rolled sections and bars intended for use in boiler, pressure vessel and machinery construction are to be manufactured and tested in accordance with the requirements of this Section and the relevant parts of Q 1 and Q 2.

These requirements are related to the intended application and have been sub-divided as follows:—

##### *Rolled Steel Sections and Bars (Boiler Quality)*

Paragraphs 402 to 410 give the requirements for rolled sections and bars intended for structural purposes. These include boiler stay bars and bars for the manufacture of bolts which are not subject to dynamic loading or to creep relaxation.

##### *Rolled Steel Bars (Machinery Quality)*

Paragraphs 412 to 420 give the requirements for rolled bars intended for the manufacture (by machining operations only) of straight shafting and other important components which are subject to significant dynamic stresses but not subject to creep relaxation. These requirements are applicable only to bars with a diameter not exceeding 250 mm and larger items are to be manufactured and tested in accordance with Q 6.

(b) Rolled bars intended for re-forging are to be manufactured in accordance with the requirements of Q 6 but mechanical tests are not required at the rolling mill.

(c) Bolts for turbine casings, steam pipe joints and other applications subject to creep relaxation are to be manufactured in accordance with an approved specification.

(d) In the case of sections and bars intended for special low temperature service, where the steel is to have guaranteed Charpy V-notch impact values at low temperatures, details of the proposed specification are to be submitted for approval.

(e) At the discretion of the Surveyor, a modified testing procedure may be adopted for small quantities of material. In such cases short lengths may be accepted on the manufacturer's declared chemical composition and hardness tests or other evidence of satisfactory properties.



(f) Alternatively, steel sections complying with national or proprietary specifications may be accepted provided these specifications give reasonable equivalence to the requirements of this Section.

## ROLLED STEEL SECTIONS AND BARS

### (Boiler Quality)

402 Rimming or free-cutting steels are not permitted. Any other method of de-oxidation may be used except that for steel with guaranteed low temperature impact properties, the method of de-oxidation is to be in accordance with the approved specification.

### Chemical Composition

403 The chemical composition is to comply with the requirements given in Table Q 4.1.

The chemical composition of steels for special low temperature service is to comply with the approved specification.

### Heat Treatment

404 Sections and bars may, at the option of the manufacturer be supplied either in the "as rolled" or normalized condition.

Steels with guaranteed low temperature impact properties are to be heat treated in accordance with the approved specification.

### Test Material

405 (a) Sections and bars are to be presented for testing in batches containing not more than 50 lengths or 10 tonnes whichever is less. The material in each batch is to be of the same section size and from the same cast. If the sections are supplied in the heat treated condition, the material in each batch is to be subjected to the same finishing treatment in a continuous furnace or heat treated in the same furnace charge in a batch type furnace.

At least one tensile test piece is to be taken from material representative of each batch. Bend test pieces are to be taken from each piece (*see* Q 105(b)).

When required, a set of three Charpy V-notch test pieces are to be taken from material representative of each batch.

(b) All test pieces are to be cut parallel to the direction of rolling. Any straightening of test pieces, which may be required, is to be done cold.

When required, Charpy V-notch impact test pieces are to be cut from the following positions:—

Flats, round and square bar:— At approximately two-thirds radius from the axis of the flat or bar.

Angles and tees:— On thickest leg approximately one-third from the outer edge.

Joists and channels:— On thickest flange at approximately one-third from the outer edge.

### Mechanical Properties

406 The results of all tensile tests are to comply with the values given in Table Q 4.2. Bend test pieces are to withstand being bent through an angle of 180° round a former having a diameter not greater than that specified in the above Table.

For steels intended for special low temperature service the Charpy V-notch tests are to be carried out at the reference test temperature given in the order (*see* Q 101(c)). The results of tensile, bend and Charpy V-notch impact tests are to comply with the approved specification.

### Inspection

407 Inspection is to be carried out in accordance with Q 107.

### Repair of Defects

408 The repair of defects by welding at the steelworks is not acceptable but proposals for the repair of minor surface defects by the fabricator in accordance with Q 108 will be considered.

### Identification

409 Sections are to be identified in accordance with Q 109.

### Documentation

410 The manufacturer is to supply the information detailed in Q 110.

## ROLLED STEEL BARS

### (Machinery Quality)

### Scope

411 These requirements apply to rolled bars not exceeding 250 mm diameter which are intended for the manufacture (by machining operations only) of straight shafting and other important components which are subject to significant dynamic stresses but not subject to creep relaxation.

Larger items are to be manufactured and tested in accordance with Q 6.



**TABLE Q 4.1**  
**CHEMICAL COMPOSITION OF SECTIONS AND BARS (BOILER QUALITY)**

GRADE OF STEEL	TENSILE STRENGTH	CHEMICAL COMPOSITION OF LADLE SAMPLES—PERCENTAGE					
	N/mm <sup>2</sup>	C	Si	Mn	S	P	Residual Elements
Carbon and Carbon-Manganese	410–510	0,20 max.	0,35 max.	0,50–1,30	0,050 max.	0,050 max.	Ni 0,30 max. Cr 0,25 max. Mo 0,10 max. Cu 0,30 max.
	460–560	0,20 max. (Note 1)	0,35 max.	0,60–1,40 (Note 2)	0,050 max.	0,050 max.	Total 0,70 max.

NOTES. 1. For material over 30 mm in thickness. Carbon 0,22 per cent max.

2. For sections used in welded machinery structures and for boiler stay bars,  $C + \frac{Mn}{6}$  is not in general to exceed 0,41 per cent.

**TABLE Q 4.2**  
**MECHANICAL PROPERTIES OF SECTIONS AND BARS (BOILER QUALITY)**

GRADE OF STEEL	MINIMUM YIELD STRESS N/mm <sup>2</sup> FOR THICKNESS OR DIAMETER in mm (NOTE 1)			TENSILE STRENGTH N/mm <sup>2</sup>	ELONGATION ON $5,65\sqrt{S_0}$ % MINIMUM (NOTE 2)	BEND TEST MAX. DIAMETER OF FORMER
	Up to 16	Over 16 to 40	Over 40 to 63			
Carbon and Carbon-Manganese	230	220	210	410–510	23	2t
	260	250	240	460–560	21	3t

t = thickness of bend test piece.

NOTES. 1. These values apply only to material with a thickness or diameter less than 63 mm. For material over 63 mm the yield stress values are to be reduced by 1 per cent for each 5 mm increase in thickness or diameter over 63 mm.

2. For material over 63 mm in thickness or diameter the minimum elongation values are to be reduced by 1.

#### Manufacture

**412** Bars are to be manufactured in accordance with the requirements of Q 602. The use of rimming, free-cutting or semi-killed steel is not acceptable.

#### Chemical Composition

**413** The chemical composition is to comply with the requirements of Q 603.

#### Heat Treatment

**414** Bars are to be supplied in the normalized or other approved condition of heat treatment.

#### Test Material

**415** Material is to be presented for test in batches. A batch is to consist of either:—

(i) material from the same piece or rolled length (see Q 105(b)) provided that where this is cut into individual lengths, these are all heat treated in the same furnace charge.

or (ii) bars of the same diameter and cast, heat treated in the same furnace charge and with a total weight not exceeding 1 tonne.

One tensile and one bend test piece are to be taken from each batch, and are to be machined in accordance with Q 2.

**Mechanical Properties**

**416** The results of all tensile tests are to comply with the requirements of Q 606. Bend test pieces are to withstand being bent through an angle of 180° round a former having a diameter not greater than that specified in Table Q 6.3.

**Inspection**

**417** Inspection is to be carried out in accordance with Q 107.

**Repair of Defects**

**418** The repair of defects by welding is not permitted.

**Identification**

**419** The rolled bars are to be identified in accordance with Q 109.

**Documentation**

**420** The manufacturer is to supply the information detailed in Q 110.

**Section 5****STEEL CASTINGS****Scope**

**501** (a) Important steel castings intended for use in boiler, pressure vessel and machinery construction are to be manufactured and tested in accordance with the requirements of this Section and the relevant parts of Q 1 and Q 2.

The requirements for castings intended for pressure containment or for general machinery construction are given in 501 to 510. Steel castings for crank shafts are to comply with the requirements given in 511 to 520. The requirements for steel propeller castings are given in 521 to 530. Reference should be made to Q 8 for the requirements relevant to cast iron crank shafts and to Q 9 for copper alloy propellers.

Where small and identical castings are produced in large quantities, the Surveyor may adopt an alternative system of quality control provided it is approved and the required standard of inspection is maintained by the manufacturer.

**CASTINGS FOR PRESSURE CONTAINMENT AND GENERAL MACHINERY CONSTRUCTION**

(b) The requirements in 502 to 510 are primarily intended for castings such as valve bodies and fittings for boilers and pressure vessels, where the design pressure is in excess of 0.98 N/mm<sup>2</sup> (10 kgf/cm<sup>2</sup>), turbine casings and associated castings. Castings for general machinery construction, excluding crankshafts and propellers, are also to be manufactured and tested to these requirements.

Provision is made for four categories of castings which differ mainly in respect of testing procedures and are intended for the following uses:—

- Category I Where design is based on guaranteed values for elevated temperature properties.
- Category II(a) Where design is based on nominal values for elevated temperature properties, which are not required to be proved by test.
- II(b) Castings for general machinery construction.
- Category III For special low temperature service where the steel is to have guaranteed low temperature Charpy V-notch properties. In this case the proposed specification is to be submitted for approval.

Alternatively, steel castings complying with National or proprietary specifications may be accepted provided these specifications give reasonable equivalence to the requirements of this Section.

**Manufacture**

**502** All castings are to be made at foundries approved by the Committee.

Steel is to be manufactured in accordance with Q102 (a).

All flame cutting or scarfing to remove surplus metal is to be completed before final heat treatment of the casting and pre-heating is to be applied when necessary. Alloy steel castings are generally to be given a preliminary annealing heat treatment prior to flame cutting or scarfing. The affected areas are to be ground smooth.

**Chemical Composition**

**503** For Categories I and II the chemical composition is to comply with the requirements given in Table Q 5.1.

Where it is proposed to use steels of higher carbon content or alloy steels not specified in Table Q 5.1, details of the chemical composition, heat treatment and mechanical properties are to be submitted for approval.

The chemical composition of castings for Category III is to comply with the approved specification.

**Heat Treatment**

**504** (a) Steel castings are to be uniformly heated to a temperature above the upper critical point to refine the grain structure and are to be:—

- (i) fully annealed by cooling slowly in the furnace in a uniform manner,
- or (ii) normalized by cooling in air,



TABLE Q 5.1

## CHEMICAL COMPOSITION OF CASTINGS FOR PRESSURE CONTAINMENT AND GENERAL MACHINERY CONSTRUCTION

GRADE OF STEEL	TENSILE STRENGTH	CHEMICAL COMPOSITION OF LADLE SAMPLES—PER CENT									
	N/mm <sup>2</sup>	C max.	Si	Mn	S max.	P max.	Ni max.	Cr	Mo	Cu max.	V
Carbon	400–510	0,20	0,15–0,60	0,50–1,00	0,050	0,050	0,40	0,25 max.	0,15 max.	0,30 (see Note)	—
	430–540	0,25	0,15–0,60	0,60–1,20	0,050	0,050	0,40	0,25 max.	0,15 max.	0,30 (see Note)	—
Carbon-Manganese	430–540	0,17	0,15–0,60	0,90–1,60	0,050	0,050	0,40	0,25 max.	0,15 max.	0,30 (see Note)	—
$\frac{1}{2}$ Mo	430–590	0,25	0,15–0,50	0,50–1,00	0,050	0,050	0,40	0,25 max.	0,40–0,70	0,30	—
1Cr– $\frac{1}{2}$ Mo	460–690	0,23	0,15–0,60	0,50–0,80	0,050	0,050	0,40	1,00–1,50	0,45–0,65	0,30	—
2 $\frac{1}{4}$ Cr–1Mo	460–690	0,20	0,15–0,60	0,40–0,70	0,050	0,050	0,40	2,00–2,75	0,90–1,20	0,30	—
$\frac{1}{2}$ Cr– $\frac{1}{2}$ Mo– $\frac{1}{4}$ V	510–690	0,18	0,15–0,50	0,40–0,80	0,050	0,050	0,40	0,25–0,50	0,50–0,70	0,30	0,22–0,30

NOTE. Total residual elements 0,80 per cent maximum.

- or (iii) normalized by cooling in air followed by a tempering treatment. For carbon and carbon-manganese steel castings this tempering temperature is to be not less than 600°C.
  - or (iv) a combination of the above treatments consisting of annealing or homogenizing at a relatively high temperature as a preliminary refining treatment to subsequent normalizing and tempering.
- (b) All alloy steel castings are to be heat treated as in (iv) above at temperatures suitable for the chemical composition and specified mechanical properties.
- (c) Turbine casings and castings of structural importance, e.g. castings for engine bedplates, are to be heat treated by methods (i), (iii), or (iv) as above. After either full annealing as in (i), or tempering, as in (iii) or (iv), the castings are to be furnace cooled to a temperature of 200°C or less.
- (d) When it is proposed to adopt other heat treatments full details are to be submitted for approval.

#### Test Material

**505** (a) Test material is to be cast attached to each casting at positions agreed between the manufacturer and Surveyor. In all cases both the test material and the casting are to be identified by the Surveyor before separation.

When a number of castings, each less than 500 kg in weight, are produced from one cast and they are heat treated together in one furnace then a system of batch testing may be adopted. The number of tests required and the method of providing the test material is to be agreed with the Surveyor.

(b) The test material is not to be detached from the casting it represents until all heat treatment has been completed.

(c) Category I. At least one tensile and bend test is to be made at ambient temperature for each casting. When large castings are made from more than one cast of steel or are of complex design, the number and location of test material is to be agreed with the Surveyor.

A tensile test at elevated temperature is to be made for each casting, in accordance with Q 205, except when:—

- (i) the reference test temperature is 100°C or less,
- (ii) the specified minimum value for the 0,2 per cent proof stress value at the reference test temperature is higher than the corresponding stress-to-rupture value.

(d) Category II. Test material is to be provided for the tests specified in 505(c), except that tensile tests at elevated temperatures are not required.

(e) Category III. Test material is to be provided for the tests specified in 505(d) and for one set of Charpy V-notch test pieces.

(f) The dimensions of the tensile and bend test pieces are to comply with Q 2. Test pieces for tensile tests at ambient temperature are to have a diameter of not less than 14 mm.

Impact test pieces are to be machined in accordance with Q 2.

#### Mechanical Properties

**506** (a) Category I. The results of all tensile tests at ambient temperature and the lower yield or 0,2 per cent proof stress values at the reference test temperature given in the order are to comply with the values given in Table Q 5.2.

Bend test pieces are to withstand being bent through an angle of 120° round a former having a diameter not greater than that specified in Table Q 5.2.

(b) Category II. The results of tensile tests at ambient temperature are to comply with the values given in Table Q 5.2. For design purposes this Table also contains nominal values of yield or 0,2 per cent proof stress values at elevated temperatures for carbon and carbon-manganese steels.

Bend test pieces are to withstand being bent through an angle of 120° round a former having a diameter not greater than that specified in Table Q 5.2.

(c) Category III. The Charpy V-notch tests are to be made at or below the reference test temperature given in the order. The results of the tensile, bend and Charpy V-notch tests are to comply with the approved specification.

(d) If for any reason after testing as above, a casting is given a further full annealing or normalizing and tempering heat treatment, e.g. after weld repairs, then the original tests are to be disregarded and further complete mechanical tests are to be made.

#### Inspection

**507** (a) The manufacturer is expected to make any tests necessary to prove the casting technique for prototype castings.

When castings are produced in regular quantities the manufacturer is expected to make periodical examinations to verify the continued efficiency of the manufacturing technique and the Surveyor is to be given the opportunity to witness these tests.



TABLE Q 5.2

## MECHANICAL PROPERTIES OF CASTINGS FOR PRESSURE CONTAINMENT AND GENERAL MACHINERY CONSTRUCTION

GRADE OF STEEL	YIELD STRESS MINIMUM N/mm <sup>2</sup>	TENSILE STRENGTH N/mm <sup>2</sup>	ELONGATION ON $5,65\sqrt{S_0}$ % MINIMUM	REDUCTION OF AREA % MINIMUM	BEND TEST, MAXIMUM DIA. OF FORMER	MINIMUM LOWER YIELD OR 0,2% PROOF STRESS N/mm <sup>2</sup> (=MPa)						
						100°C	150°C	200°C	250°C	300°C	350°C	400°C
CATEGORY I												
Carbon	220	400-510	22	35	3t	179	173	167	156	139	131	127
Carbon	240	430-540	22	35	3t	200	185	182	170	157	147	137
Carbon-Manganese	240	430-540	22	35	3t	200	185	182	170	157	147	137
$\frac{1}{2}$ Mo	235	430-590	18	30	3t	Values by agreement with the manufacturer						
1Cr- $\frac{1}{2}$ Mo	255	460-690	17	30	3t							
2 $\frac{1}{4}$ Cr-1Mo	255	460-690	17	30	6t							
$\frac{1}{2}$ Cr- $\frac{1}{2}$ Mo- $\frac{1}{4}$ V	285	510-690	17	30	6t							
CATEGORY II						LOWER YIELD OR 0,2% PROOF STRESS, N/mm <sup>2</sup> (=MPa) (see NOTE)						
Carbon	205	400-510	22	35	3t	166	159	156	143	127	117	113
Carbon	220	430-540	22	35	3t	179	170	167	153	139	129	127
Carbon-Manganese	220	430-540	22	35	3t	179	170	167	153	139	129	127

t = thickness of bend test piece.

NOTE. These values are included for design purposes and do not require to be proved by test.

(b) All castings are to be cleaned and adequately prepared for inspection. Suitable methods include pickling, caustic cleaning, wire brushing, local grinding, shot or sand blasting. The surface finish is to be in accordance with good practice and any specific requirement of the Engine-builder. Before examination, the surfaces must not be hammered, peened or treated in any way which may obscure defects.

Turbine casings are to be examined by magnetic particle method in, at least, all areas containing changes of section and where surplus metal has been removed by flame cutting. Where component castings are to be welded together to form a turbine casing, the material in way of the weld preparations in the component castings is to be examined by radiography. This examination is to be carried out prior to welding.

Castings of structural importance, which in service are subject to significant fatigue loading conditions, e.g. castings for engine bedplates, are also to be examined by magnetic particle methods at positions of high stress.

In all cases supplementary examinations by radiography, ultrasonic or other approved methods of non-destructive testing in order to determine the soundness of the castings may also be requested. This examination should include verification of wall thickness, where appropriate. When such examination is to be carried out, it should be at positions, mutually agreed by the Surveyor, manufacturer and Enginebuilder, where experience shows that cavities, contraction cracks or other defects are most likely to occur. For piston head and cylinder cover castings the manufacturer is to provide the Surveyor with a signed statement that non-destructive testing by an approved procedure has been carried out with satisfactory results. Details of the procedure used are to be stated.

(c) The Surveyor is to examine each large casting, including piston head and cylinder cover castings, before final acceptance at the foundry.

#### Repair of Defects

508 (a) When defects are found in a casting these are to be removed by grinding or by chipping and grinding. Flame scarfing or arc-air gouging may also be used provided that pre-heating is employed when necessary and that the surfaces of the resulting depressions are subsequently ground smooth. Complete elimination of the defective material is to be proved by magnetic particle tests. Shallow grooves or depressions resulting from the removal of defects can, at the Surveyor's discretion, be accepted provided these are blended by grinding.

(b) Proposals to repair a defective casting by welding are to be submitted to the Surveyor before work is com-

menced. The Surveyor is to satisfy himself that the number and size of the defects are such that the casting can be efficiently repaired.

When it has been agreed that the casting can be repaired the procedure is to be in accordance with Q 108 and the area is to be prepared in a form suitable for welding. All castings in alloy steels and, if necessitated by the shape, castings in carbon or carbon-manganese steels are to be given a preliminary refining heat treatment prior to carrying out weld repairs. An electric arc welding process is to be used and the weld deposit is to have properties similar to and in no way inferior to the parent metal. Welding of the affected parts is to be undertaken by a procedure the essential elements of which have been tested previously by the manufacturers and approved by the Surveyor. The welding is to be done under cover in positions free from draughts and adverse weather conditions by competent welders with adequate supervision.

After welding, the castings are to be suitably heat treated either by annealing, normalizing and tempering or stress relieving at a temperature of not less than 600°C. The type of heat treatment employed will be dependent on the size, position and nature of the defects. On completion of heat treatment, the weld repairs and adjacent metal are to be ground smooth and proved by a suitable method of magnetic particle inspection. Subject to the approval of the Surveyor, a local stress relieving heat treatment may be carried out where the area involved is small and machining of the casting has reached an advanced stage.

#### Identification

509 Castings are to be identified in accordance with Q 109.

#### Documentation

510 The manufacturer is to supply the information detailed in Q 110 and is to provide the Surveyor with a statement and/or sketch detailing the extent and location of the welded repairs made to each casting together with details of the heat treatment carried out at all stages.

### CASTINGS FOR CRANKSHAFTS

#### Scope

511 Steel castings for crankshafts are to be manufactured and tested in accordance with 511 to 520 and the relevant parts of Q 1 and Q 2.

Alternatively, steel castings which comply with national or proprietary specifications may be accepted, provided these specifications give reasonable equivalence to the requirements of this Section.



**Manufacture**

512 Castings are to be manufactured in accordance with 502.

The castings are to be produced by an approved method.

**Chemical Composition**

513 The chemical composition of ladle samples is to be within the following limits:—

Carbon	0,40% max.	Copper	0,40% max.
(see Note)		Nickel	0,40% max.
Silicon	0,15–0,60%	Chromium	0,40% max.
Manganese	0,60% min.	Molybdenum	0,20% max.
Sulphur	0,040% max.	Total (Cu+Ni+Cr+Mo)	
Phosphorus	0,040% max.		1,0% max.

NOTE. Weld repairs will not be permitted when the carbon content of the steel exceeds 0,30% or its carbon equivalent, given by

$$C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15}, \text{ exceeds } 0,65\%$$

(See Chapter R(H) for further requirements)

Where it is proposed to use steel of higher carbon content or alloy steels, details of the chemical composition, heat treatment and mechanical properties are to be submitted for approval.

**Heat Treatment**

514 Castings are to be heat treated in accordance with methods (i), (iii) or (iv) of 504(a). After either full annealing, as in (i) or tempering, as in (iii) or (iv) the castings are to be furnace cooled to a temperature of 200°C or less.

**Test Material**

515 (a) The test material is to be provided as an integral part of each casting. At least one tensile and one bend test piece are required from each casting.

(b) Test pieces are to be prepared in accordance with Q 2. The diameter of the tensile test piece is to be not less than 14 mm unless otherwise agreed.

**Mechanical Properties**

516 The tensile strength is to comply with the range specified in the order which is not to exceed 110 N/mm<sup>2</sup> (11 kgf/mm<sup>2</sup>) within the general limits of 430 and 640 N/mm<sup>2</sup>.

The yield stress is to be not less than half the actual tensile strength.

The elongation and reduction of area values are to comply with the values given in Table Q 5.3 appropriate to the actual tensile strength.

Bend test pieces are to withstand being bent through an angle of 180° round a former having a diameter not greater than two times the thickness of the test piece. Where the actual tensile strength of the steel is in excess of 540 N/mm<sup>2</sup> the diameter of the former may be increased to three times the thickness of the test piece.

TABLE Q 5.3  
MECHANICAL PROPERTIES OF CASTINGS  
FOR CRANKSHAFTS

ACTUAL TENSILE STRENGTH N/mm <sup>2</sup>	ELONGATION ON $5,65\sqrt{S_o}$ % MINIMUM	REDUCTION OF AREA % MINIMUM
Over 430 to 490	24	40
„ 490 to 540	22	35
„ 540 to 590	19	30
„ 590 to 640	17	30

**Inspection**

517 (a) The manufacturer is to make any tests necessary to prove the casting technique for prototype castings.

The Surveyor is to examine each casting before final acceptance at the foundry.

(b) Crankweb and combined web and pin castings are to be examined by magnetic particle methods on all surfaces. For this purpose “as cast” surfaces are to be cleaned and prepared for inspection. Suitable methods include pickling, caustic cleaning, wire brushing, local grinding, shot or sand blasting. Before examination, the surfaces must not be hammered, peened or treated in any way which may obscure defects.

Any irregularities on surfaces which may interfere with the detection of defects should be smoothed by local grinding. It is recommended that a preliminary examination should be carried out before final heat treatment but all machined surfaces are to be examined in the finished condition by suitable magnetic particle methods.

Manufacturers are to carry out an ultrasonic test on each casting and are to provide the Surveyor with a signed statement that such inspection has not revealed any significant internal defects.



**Repair of Defects**

518 (a) When defects are found in a casting these are to be removed by grinding or by chipping and grinding. Flame scarfing or arc-air gouging may also be used provided that preheating is employed when necessary and that the surfaces of the resulting depressions are subsequently ground smooth. Complete elimination of the defective material is to be proved by magnetic particle tests. Shallow grooves or depressions resulting from the removal of defects can, at the Surveyor's discretion, be accepted provided these are blended by grinding.

(b) The acceptance of repair by welding is subject to special consideration and any action is to be in accordance with the provisional Rules for repairs by welding to steel castings for crankshafts contained in Chapter R(H).

**Identification**

519 Castings are to be identified in accordance with Q 109.

**Documentation**

520 The manufacturer is to supply the information detailed in Q 110. In addition the Surveyor is to be provided with:—

- (i) a statement and/or sketch detailing the extent and location of all welded repairs made to each casting together with details of the heat treatment carried out at all stages
- (ii) a certificate of ultrasonic examination as required by 517(b).

**CASTINGS FOR PROPELLERS****Scope**

521 Steel castings for propellers may be made in carbon, low alloy or stainless steel and are to be manufactured and tested in accordance with 521 to 530 and the relevant parts of Q 1 and Q 2. These only give outline requirements and details of the proposed chemical composition, heat treatment and mechanical properties are to be submitted for approval.

In this Section the term "severe ice service" is intended to indicate use in icebreakers or ships with Class 1\*, Class 1, Class IA Super, Class IA, Class IB or Class IC ice strengthening.

**Manufacture**

522 Castings are to be manufactured in accordance with 502. Ferritic steel for propellers intended for severe ice service is to be made by a fine grain practice.

**Chemical Composition**

523 The chemical composition is to comply with the approved specification.

**Heat Treatment**

524 Castings are to be heat treated in accordance with 504(a) and with the approved specification.

**Test Material**

525 (a) Test material is to be provided integral with the hub of propeller castings and with the flange or propeller blade castings.

At least one tensile and one bend test piece are to be taken from each casting. In addition, a set of Charpy V-notch test pieces is to be taken from all carbon or low alloy steel castings intended for severe ice service and from all ferritic or martensitic type stainless steel castings. Impact tests are not required from carbon or low alloy steel castings intended for general service or from austenitic stainless steel castings regardless of service.

(b) All test pieces are to be prepared in accordance with Q 2. The diameter of the tensile test piece is to be not less than 14 mm unless otherwise agreed.

**Mechanical Properties**

526 (a) The results of all tensile and bend tests are to comply with the approved specification.

(b) The Charpy V-notch tests are to be made at or below the following temperatures:—

Carbon, low alloy, ferritic or martensitic type stainless steel propellers intended for severe ice service:—  
test temperature  $-10^{\circ}\text{C}$ .

Ferritic or martensitic type stainless steel propellers intended for general service:—test temperature  $0^{\circ}\text{C}$ .

The average value for the Charpy V-notch tests is to be not less than 21 J. When the average result fails to meet this value, re-tests in accordance with Q 106(b) may be carried out, irrespective of the actual average value obtained.

The results of the re-tests are to be added to the original values and the average is to be not less than 21 J. For martensitic 13 per cent chromium steel propeller castings, special consideration will be given to acceptance if the average value obtained is not less than 14 J.

**Inspection**

527 The Surveyor is to examine each casting before final acceptance at the foundry. The surfaces of the blade roots are to be examined by magnetic particle methods or in the case of austenitic stainless steel by dye penetrant methods.



**Repair of Defects**

528 The removal of minor surface defects by grinding and weld repairs are to be carried out in accordance with the requirements of 508.

**Identification**

529 Castings are to be identified in accordance with Q 109.

**Documentation**

530 The manufacturer is to supply the information detailed in Q 110 and is to provide the Surveyor with a statement and/or sketch detailing the extent and location of the repairs of welding made to each casting together with details of the heat treatment carried out at all stages.

**Section 6****STEEL FORGINGS****Scope**

601 Important steel forgings intended for use in boilers, pressure vessels and machinery construction are to be manufactured and tested in accordance with the requirements of this Section and the relevant parts of Q 1 and Q 2.

In this Section the term "severe ice service" is intended to indicate use in ice breakers or for ships with Class 1\* or Class 1 ice strengthening.

Requirements for general forgings including screw shafts for severe ice service are given in 601 to 610. Requirements for the following particular forgings are given in the sub-sections indicated:—

	<i>Paragraphs</i>
Crankshaft forgings	611 to 620
Gear forgings	621 to 630
Turbine forgings	631 to 640
Forgings for boilers and pressure vessels	641 to 650

The requirements for shafts machined from hot rolled bars are given in Q 4.

Where small and identical forgings are produced in large quantities, the Surveyor may adopt an alternative system of quality control provided it is approved and the required standard of inspection is maintained by the manufacturer.

**GENERAL FORGINGS****Manufacture**

602 (a) The forgings are to be manufactured from killed steel. Screwshafts intended for severe ice service and other forgings for low temperature service are to be made from grain controlled steel.

(b) When forgings are made from ingots, or from blooms forged from ingots, the ingots are to be cast in metal moulds with the larger cross-section uppermost and with efficient feeder heads. The forgings are to be gradually and uniformly hot worked and are to be brought as nearly as possible to the finished shape and size. Where practicable they are to be worked so as to cause metal flow in the most favourable direction having regard to the mode of stressing in service. Adequate top and bottom discards are to be made to ensure freedom from piping and harmful segregations in the finished forgings.

Unless otherwise approved the maximum sectional area of any part of a forging (as forged) is not to exceed:—

$\frac{1}{3}A$  where the length of any section is greater than its diameter,

$\frac{2}{3}A$  where the length of any section is less than its diameter (e.g. a collar),

$A$  is the average sectional area of the ingot or of the ingot after upsetting if such an operation is involved.

(c) When forgings are made from rolled products the maximum sectional area of a forging (as forged) is not to exceed:—

(i) when made from products rolled from ingots cast large end uppermost with efficient feeder heads,

$\frac{1}{4}A$  where the length of any section is greater than its diameter,

or  $\frac{1}{2}A$  where the length of any section is less than its diameter (e.g. a collar),

or (ii) when made from products rolled from other types of ingots,

$\frac{1}{5}A$  where the length of any section is greater than its diameter,

or  $\frac{1}{3}A$  where the length of any section is less than its diameter (e.g. a collar),

$A$  is the average cross-sectional area of the original ingot.

(d) Disc or ring type forgings are to be made from pieces which have been hot cut or machined from a billet, bloom or ingot. The thickness of any part of a disc (as forged or as stamped) is to be not more than:—

one-half of the original length of the piece when this has been cut from a billet or bloom,



or one-third of the original length of the piece when this has been cut from an ingot.

(e) The shaping of forgings or thick slabs by flame cutting is to be undertaken in accordance with a procedure approved by the Surveyor. Where possible, flame cutting is to be carried out before the heat treatment operation of 604. Pre-heating is to be employed when necessitated by the thickness and/or composition of the steel.

For machinery parts that are subjected to significant fatigue stresses during service, a depth of at least 7,5 mm is to be removed by machining from all flame cut surfaces. If required by the Surveyor, selected areas of such machined surfaces are to be prepared and then examined by magnetic crack detection or other equivalent method to his satisfaction.

#### Chemical Composition

603 (a) For forgings in carbon and carbon-manganese steels and which are not intended for welding, the chemical composition of the ladle sample is to comply with the following:—

Carbon	0,50% max.
Silicon	0,10% to 0,45%
Manganese	0,30% to 1,5%
Sulphur	0,050% max.
Phosphorus	0,05% max.

When it is proposed to use a steel of higher carbon content, or an alloy steel, details of the proposed composition, heat treatment and properties are to accompany the plans which are submitted for approval by the builder.

(b) Forgings to which structural items are to be attached by welding or which are intended for parts of a fabricated component are to be of weldable quality with a carbon content generally not exceeding 0,23 per cent. Where the carbon content exceeds 0,23 per cent, details of the chemical composition, heat treatment and mechanical properties are to be submitted for approval.

#### Heat Treatment

604 All forgings are to be fully heat treated before being put into service. Procedures must be such as to ensure that if full treatment is not carried out by the forgemaster adequate provision with regard to test material is to be made for any treatment to be carried out at a later stage.

Forgings are to be heated to a uniform temperature above the upper critical point to refine the grain and are to be:—

- (i) Fully annealed by cooling slowly in the furnace in a uniform manner,

or (ii) normalized by cooling in air followed by a tempering treatment to relieve internal stresses if the diameter of the body of the forging is equal to or greater than the values given in Table Q 6.1. Smaller diameter forgings may also be tempered after the normalizing heat treatment at the option of the forgemaster,

or (iii) hardened by quenching in oil followed by tempering. Unless otherwise agreed, all large forgings are to be rough machined prior to the hardening heat treatment.

Where it is proposed to use other methods for hardening, full details are to be submitted for approval.

TABLE Q 6.1

#### DIMENSIONS OF FORGINGS TO BE TEMPERED AFTER NORMALIZING

% CARBON CONTENT OF STEEL		EQUIVALENT DIAMETER OF BODY OF FORGING
OVER	UP TO AND INCLUDING	
0,40	0,50	400 mm
0,35	0,40	500 mm
0,30	0,35	700 mm
0,25	0,30	900 mm
	0,25	1000 mm

#### Test Material

605 (a) Test material is to be provided integral with the forging and with a cross-sectional area of not less than that of the main part of the forging. At least one tensile and one bend test are to be taken from each forging, except where both the weight and length are in excess of 4 tonnes and 3 m respectively when tensile and bend tests are to be taken from each end. These limits refer to the "as forged" weight and length but excluding the test material.

(b) When a forging is subsequently divided into a number of items all of which are heat treated together in the same furnace then for test purposes this may be considered as one forging and the test material required is to be related to the total length and weight of the original forging.

Where a number of separate forgings are made from one cast of steel and are heat treated together in one furnace then a system of batch testing may be adopted. The number of tests required and the method of providing the test material is to be agreed with the Surveyor.

(c) Tensile and bend test pieces are to be cut longitudinally or parallel to the direction of principal grain flow.



Where test pieces cannot reasonably be provided in the longitudinal direction they may be cut in a transverse direction.

(d) The dimensions of the tensile test pieces are to comply with Q 2 and they are to have a diameter of not less than 14 mm except where the dimensions of the forging will not permit this diameter of test piece being prepared. In such cases the test piece is to be of the largest practicable diameter.

Bend test pieces are to be machined in accordance with Q 2, the subsidiary test piece (20 mm by 10 mm) being used when the specified minimum tensile strength is in excess of 540 N/mm<sup>2</sup>.

(e) For screwshafts intended for severe ice service, in addition to the tensile and bend tests, Charpy V-notch tests are to be taken from the test material at the propeller end of each shaft. The test pieces are to be cut in a longitudinal direction and the dimensions are to be in accordance with Q 2.

#### Mechanical Properties

**606** (a) The tensile strength of steel forgings is to comply with the range specified in the order. With the exception of screwshafts and propeller nuts the specified range for carbon and carbon-manganese steel forgings is not to exceed 100 N/mm<sup>2</sup> (10 kgf/mm<sup>2</sup>) within the general limits of 430 and 690 N/mm<sup>2</sup>.

When it is proposed to use a carbon or carbon-manganese steel of higher tensile strength full details are to be submitted for approval.

(b) Screwshafts are, in general, to be restricted to a range of tensile strength between 430 and 510 N/mm<sup>2</sup>.

(c) Material for propeller nuts may be within the limits of 340 and 400 N/mm<sup>2</sup>.

(d) The percentage elongation is not to be less than the value given in Table Q 6.2 appropriate to the actual tensile strength of the steel.

Bend test pieces are to withstand being bent without fracture through an angle of 180° round a former having a diameter not greater than that specified in Table Q 6.3.

Charpy V-notch tests from screwshafts intended for severe ice service are to be carried out at -10°C and are to give an average energy value of not less than 21 J.

#### Inspection

**607** (a) The Surveyor is to examine each forging before final acceptance at the forge.

TABLE Q 6.2

TENSILE PROPERTIES OF CARBON STEEL FORGINGS

ACTUAL TENSILE STRENGTH  N/mm <sup>2</sup>	ELONGATION ON 5,65√S <sub>0</sub> % MINIMUM	
	LONGITUDINAL OR IN THE DIRECTION OF PRINCIPAL GRAIN FLOW	TRANSVERSE OR ACROSS THE DIRECTION OF PRINCIPAL GRAIN FLOW
340 to 390	27	22
Over 390 to 440	25	21
„ 440 to 490	23	19
„ 490 to 540	22	18
„ 540 to 590	20	16
„ 590 to 640	18	14
„ 640 to 690	16	12

TABLE Q 6.3

BEND TESTS FOR CARBON STEEL FORGINGS

ACTUAL TENSILE STRENGTH  N/mm <sup>2</sup>	MAXIMUM INTERNAL DIAMETER OF BEND OR DIAMETER OF FORMER	
	LONGITUDINAL OR IN THE DIRECTION OF PRINCIPAL GRAIN FLOW	TRANSVERSE OR ACROSS THE DIRECTION OF PRINCIPAL GRAIN FLOW
Up to 490	$\frac{2}{3}t$	$\frac{1}{3}t$
Over 490 to 590	$t$	$2t$
„ 590 to 690	$2t$	$4t$
Where t=thickness of test piece		

(b) Unless otherwise agreed, the forgemaster is to carry out an ultrasonic test on all forgings for shafts and other parts subject to significant fatigue loading, where the diameter or equivalent ruling section is 250 mm or greater and is to provide the Surveyor with a signed statement that such inspection has not revealed any significant internal defects.

(c) When small forgings are tested as a batch, the hardness of each forging is to be determined including those from which material is to be cut for the provision of tensile and bend test pieces. The hardnesses of the forgings are to comply with a specification approved by the Surveyor before manufacture of the forgings. The Surveyor is to satisfy himself that the inspection procedure for surface condition and soundness adopted by the manufacturer is adequate.



**Repair of Defects**

608 The repair of defects by welding is not permitted.

**Identification**

609 Forgings are to be identified in accordance with Q 109.

**Documentation**

610 The manufacturer is to supply the information detailed in Q 110 and a certificate of ultrasonic examination as required by 607(b).

**CRANKSHAFT FORGINGS****Scope**

611 Solid forged crankshafts and forgings for use in the construction of built or semi-built crankshafts are to be manufactured and tested in accordance with the requirements of this Section and the relevant parts of Q 1 and Q 2.

**Manufacture**

612 Forgings are to be manufactured in accordance with the requirements of 602

For combined web and pin forgings the proposed method of forging is to be submitted for approval. It is recommended that these forgings be made by a folding method. Other methods which can be shown to produce sound forgings with satisfactory mechanical properties will be considered but where the gapping method is used for cranks having a pin diameter exceeding 510 mm this will only be accepted provided that an upsetting operation is included in the manufacturing sequence. In general, the amount of work during the upsetting operation is to be such that the reduction in the original length of the ingot (after discard) or bloom is not less than 50 per cent.

**Chemical Composition**

613 The chemical composition is to be within the limits specified in 603 unless otherwise agreed.

**Heat Treatment**

614 Forgings are to be heat treated in accordance with the requirements of 604.

**Test Material**

615 Test material is to be provided on each forging as specified in 605. On slabs for crankwebs the test pieces are to be taken transversely.

**Mechanical Properties**

616 (a) The tensile strength is to comply with the range specified in the order. The specified range for carbon and carbon-manganese steel forgings is not to exceed 100 N/mm<sup>2</sup> (10 kgf/mm<sup>2</sup>) within the general limits of 430 and 690 N/mm<sup>2</sup>.

(b) For crankwebs and other parts where minimum yield stresses are specified the yield stress is not to be less than 50 per cent of the minimum specified tensile strength. (See H 206).

(c) When it is proposed to use a steel of higher tensile strength full details, including yield stress, are to be submitted for approval.

(d) The percentage elongation is not to be less than the value given in Table Q 6.2 appropriate to the actual tensile strength of the steel.

Bend test pieces are to withstand being bent through an angle of 180° round a former having a diameter not greater than that specified in Table Q 6.3.

**Inspection**

617 (a) The Surveyor is to examine each forging before final acceptance at the forge.

(b) The forgemaster is to carry out an ultrasonic test on all forgings for crankshafts which have finished pins or journals in excess of 250 mm diameter and is to provide the Surveyor with a signed statement that such inspection has not revealed any significant internal defects.

(c) Magnetic particle examination is to be carried out on the pins and journals of all solid forged crankshafts and on the pin fillet of all combined web and pin forgings. This examination is to be carried out in the finished machined condition. Where forgings are supplied in the black or rough machined condition, this examination is to be carried out by the engine builder.

(d) When small forgings are tested as a batch, hardness tests, as detailed in 607(c), are to be carried out.

**Repair of Defects**

618 The repair of defects by welding is not permitted.

**Identification**

619 Forgings are to be identified in accordance with Q 109.

**Documentation**

620 The manufacturer is to supply the information detailed in Q 110 and a certificate of ultrasonic examination as required by 617(b).



## FORGINGS FOR REDUCTION GEARING

## Scope

621 Forgings for pinions, pinion sleeves, gear wheels and gear wheel rims intended for reduction gearing where the transmitted power exceeds 110 kW are to be manufactured and tested in accordance with the requirements of this Section and the relevant parts of Q 1 and Q 2. Where the transmitted power is less than 110 kW the manufacturer's certificate of test may be accepted.

Forgings for flexible couplings, quill shafts and gear wheel shafts are to comply with 601 to 610.

Specifications for materials of pinions, pinion sleeves, wheel rims, gear wheels, flexible couplings and quill shafts giving chemical analysis, heat treatment and mechanical properties are to be submitted for approval with the plans of gearing, as required by G 104 and H 302.

When the teeth of a pinion or gear wheel are to be surface hardened, i.e. case hardened, nitrided or induction hardened, the proposed specification together with details of the process and practice are to be submitted for approval. In general, for nitrided gears the treatment time should not be less than 60 hours. Unless otherwise agreed the specified minimum tensile strength of the core is to be 780 N/mm<sup>2</sup> for induction hardened or nitrided gearing and 740 N/mm<sup>2</sup> for case hardened gearing (see H 307). For purposes of initial approval the gear manufacturer is required to demonstrate by test that the surface hardening of the teeth is uniform and of the required depth and that it does not impair the soundness and quality of the steel.

## Manufacture

622 (a) Forgings are to be manufactured in accordance with the requirements of 602.

Sleeve forgings are to be hollow forged or hollow rolled where practicable.

Rim forgings are to be expanded by forging or rolling where practicable.

(b) All forgings are to be made with sufficient material to permit an adequate machining allowance on all surfaces for the removal of unsound or decarburized material. For alloy steel forgings the machining allowance on surfaces where teeth will be cut is to be not less than the following:—

<i>Finished diameter of toothed portion</i>	<i>Machining Allowance</i>
200 mm or less	15 mm on diameter
Over 200 mm	25 mm on diameter

## Chemical Composition

623 Gear wheel and rim forgings with a specified minimum tensile strength not in excess of 740 N/mm<sup>2</sup> may be made in carbon or carbon-manganese steel complying with the following limits:—

Carbon	0,60% max.
Silicon	0,10% to 0,45%
Manganese	0,30% to 1,50%
Sulphur	0,040% max.
Phosphorus	0,040% max.

Gear wheel or rim forgings where the specified minimum tensile strength is in excess of 740 N/mm<sup>2</sup> and all pinion or pinion sleeve forgings are to be made in a suitable alloy steel. Any of the following types of steel will be accepted:—

3% Ni
3½% Ni
1¼% Ni Cr Mo
2½% Ni Cr Mo
3% Ni Cr Mo
4¼% Ni Cr Mo
1% Cr Mo
3% Cr Mo

Where it is proposed to use other steels the proposed chemical composition is to be submitted for approval.

## Heat Treatment

624 (a) Forgings may be either normalized and tempered, oil hardened and tempered or water hardened and tempered in accordance with the approved specification. The tempering temperature is not to be less than 550°C.

At the discretion of the manufacturer, heat treatment may be carried out either in the black "as forged" condition or after rough machining. It is recommended, however, that where the finished diameter of the toothed portion exceeds 200 mm forgings should be rough machined prior to hardening and tempering.

Where forgings are machined prior to heat treatment, the allowance left for final machining is to be sufficient to remove the decarburized surface material taking into account any bending or distortion which may occur.

(b) Where induction hardening or nitriding is to be carried out after machining of the gear teeth the forgings are to be heat treated at an appropriate stage to a condition suitable for the subsequent surface hardening.

(c) Forgings for gears which are to be case hardened after final machining are to be supplied in a condition suitable for subsequent machining and case hardening.



**Test Material**

*Through hardened, induction hardened or nitrided gear forgings.*

625 (a) At least one tensile and one bend test piece are to be taken from each forging in carbon or carbon-manganese steel and at least one tensile and one set of impact tests when the forgings are to be made in alloy steel. Sufficient test material is to be provided for this purpose and the test pieces are to be taken as follows:—

- (i) Where the finished diameter over the portion where teeth will be cut is 200 mm or less, the test pieces are to be cut in a longitudinal direction from the end of the forging (see Fig. Q 6.1).

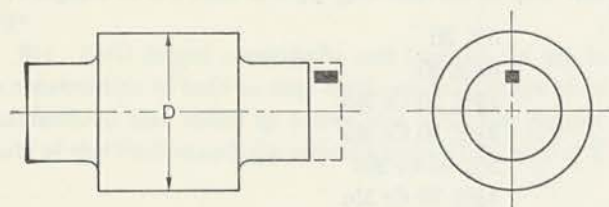


FIG. Q 6.1

Diameter D 200 mm or less

- (ii) Where the above finished diameter exceeds 200 mm the test pieces are to be cut in a transverse or circumferential direction adjacent to the position where the teeth will be cut (see Fig. Q 6.2). In the case of forgings where the diameter of the journal precludes the preparation of test pieces from this position, test material may be provided on the ends of the journals. Where the finished journal diameter is 200 mm or less these test pieces are to be cut in a longitudinal direction. Where the finished journal diameter exceeds 200 mm the test pieces are to be cut in a transverse direction (see Fig. Q 6.3).

- (iii) When the finished length of a pinion forging, excluding the journals, exceeds 1,25 m tests as prescribed in (ii) are required from each end.

- (iv) When the finished diameter of a gear wheel or rim exceeds 2,5 m or the weight (as forged) exceeds 3 tonnes, two sets of tests are to be taken from positions diametrically opposed and for gear rim forgings from opposite ends when the width of the face on which teeth will be cut exceeds 1000 mm (see Fig. Q 6.4).

(b) When a forging is subsequently divided into a number of items all of which are heat treated together in the same furnace then for test purposes this may be considered as one forging and the test material required is to be related to the total length and weight of the original forging.

Where a number of separate forgings are made from one cast of steel and heat treated together in one furnace then a system of batch testing may be adopted. The number of tests required and the method of providing the test material is to be agreed with the Surveyor.

(c) The dimensions of the tensile test pieces are to comply with Q 2 and they are to have a diameter of not less than 14 mm except where the dimensions of the forging will not permit this diameter of test piece being prepared.

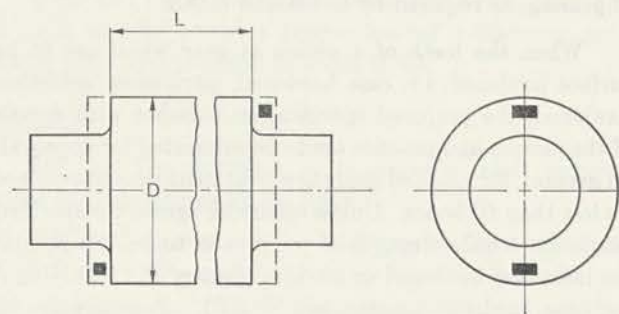


FIG. Q 6.2

Diameter D greater than 200 mm. Two sets of test pieces are required only when L is greater than 1,25 m.

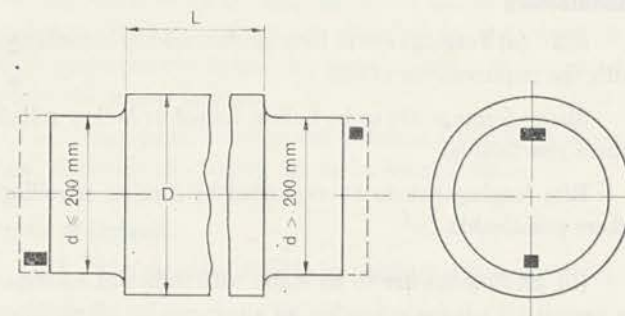


FIG. Q 6.3

Diameter D greater than 200 mm but journal diameter precludes tests as shown in Fig. Q 6.2. When journal diameter d is 200 mm or less, tests to be cut in longitudinal direction. When journal diameter d is greater than 200 mm tests to be cut in transverse direction. Two sets of test pieces are required only when length L is greater than 1,25 m.



In such cases the test piece is to be of the largest practicable diameter.

Bend test pieces are to be machined in accordance with Q 2 the subsidiary test piece (20 mm by 10 mm) being used when the specified minimum tensile strength is in excess of 540 N/mm<sup>2</sup>.

Impact test pieces are to be machined in accordance with Q 2 and may be of either the Izod, Charpy V-notch or Charpy U-notch types.

#### Case hardened gear forgings

(d) Sufficient material for test purposes both at the forgemaster's and manufacturer's works is to be provided generally as specified in (a) and (b) except that, irrespective of the dimensions or weight of the forging, tests are required from one position only and in the case of forgings with integral journals are to be cut in a longitudinal direction.

A sufficient number of test blocks with a cross-section of 63 mm diameter and of suitable length are to be machined from the test material for use at the forge and gear manufacturer's works.

For small forgings where a system of batch testing is adopted, the test blocks may be machined from test material made from surplus steel from the same cast provided that the forging reduction approximates to that of the actual gear forgings.

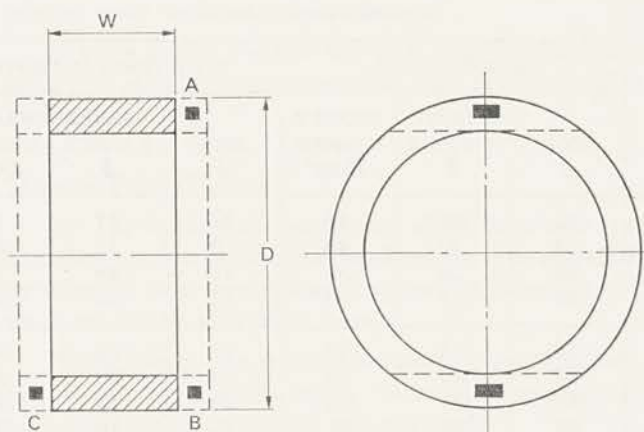


FIG. Q 6.4

Two sets of test pieces are required only when the diameter  $D$  is greater than 2,5 m or weight greater than 3 tonnes.

When the width  $W$  is 1000 mm or less tests may be taken from positions A and B. When  $W$  exceeds 1000 mm tests are to be taken from positions A and C.

Tensile and impact tests are to be taken by the forgemaster from test blocks which have been given a blank carburising and heat treatment cycle simulating that which will be subsequently applied to the forgings. These test pieces are to be prepared in accordance with (c) and are to be cut with their axis at about 12,5 mm from the surface of the test block.

A similar set of mechanical tests are also to be taken at the gear manufacturer's works from test blocks which have been blank carburized and heat treated with the gear forgings they represent.

At the discretion of the manufacturer test blocks of larger cross-section may be blank carburized but these are then to be machined to 63 mm diameter prior to the final hardening and tempering heat treatment.

Where it is proposed to adopt alternatives to the foregoing full details are to be submitted for consideration.

#### Mechanical Properties

##### Through hardened gear forgings

626 (a) The tensile strength is to be within the range specified in the order. The specified range is not to exceed 100 N/mm<sup>2</sup> (10 kgf/mm<sup>2</sup>). These ranges are to be within the general limits of 590 and 1180 N/mm<sup>2</sup> for pinions or 440 and 980 N/mm<sup>2</sup> for gear wheels. Consideration is also to be given to maintaining the necessary hardness differential between pinion and gear wheel teeth (see H 303).

The percentage elongation is not to be less than the value given in Table Q 6.4 appropriate to the specified minimum tensile strength of the steel.

Bend test pieces from carbon and carbon-manganese steel forgings are to withstand being bent through 180° round a former having a diameter not greater than that specified in Table Q 6.4.

The impact tests from alloy steel forgings are to be made at room temperature and are to give energy values not less than the appropriate value given in Table Q 6.4.

Proposals to use materials of higher tensile strength are to be submitted for approval.

##### Induction hardened and nitrided gear forgings

(b) The tensile strength is to be not less than 780 N/mm<sup>2</sup> and the percentage elongation and impact values are to be not less than those given in Table Q 6.4 for alloy steel with the above specified minimum tensile strength.

##### Case hardened gear forgings

(c) Unless otherwise agreed for tests both at the forgemaster's and gear manufacturer's works the tensile strength

is to be not less than 740 N/mm<sup>2</sup>. The percentage elongation and impact values are to be not less than the values appropriate to the actual tensile strength as given in Table Q 6.4 for oil hardened and tempered alloy steels.

### Inspection

**627** (a) The Surveyor is to examine each forging before acceptance at the forge.

(b) The forgemaster is to carry out an ultrasonic examination of all forgings where the finished diameter of

the toothed portion is in excess of 200 mm, and is to provide the Surveyor with a signed statement that such inspection has not revealed any significant internal defects.

### Hardness Tests

(c) Hardness tests are to be carried out on all forgings after completion of heat treatment and prior to machining the gear teeth, except on forgings intended for case hardening.

When the diameter of the finished item is less than 500 mm one hardness test is to be made on each forging.

TABLE Q 6.4

### MECHANICAL PROPERTIES OF GEAR FORGINGS

STEEL	HEAT TREATMENT	MINIMUM YIELD STRESS N/mm <sup>2</sup>	SPECIFIED MINIMUM TENSILE STRENGTH N/mm <sup>2</sup>	MINIMUM ELONGATION % ON 5.65√S <sub>o</sub>		BEND TEST—MAXIMUM DIAMETER OF FORMER					
				LONGL.	TRANSV. (see NOTE)	LONGITUDINAL			TRANSVERSE (see NOTE)		
Carbon or Carbon- Manganese	Normalized and Tem- pered or Oil hardened and Tempered	225	440	23	19	$\frac{2}{3}t$			$1\frac{1}{3}t$		
		245	490	22	18	$\frac{3}{4}t$			$1\frac{1}{2}t$		
		275	540	20	16	t			2t		
		295	590	18	14	t			2t		
		325	640	17	12	2t			4t		
		345	690	16	11	2t			4t		
						MINIMUM IMPACT ENERGY					
						LONGITUDINAL			TRANSVERSE (see NOTE)		
						IZOD J	CHARPY V-NOTCH J	CHARPY U-NOTCH J/cm <sup>2</sup>	IZOD J	CHARPY V-NOTCH J	CHARPY U-NOTCH J/cm <sup>2</sup>
Alloy	Normalized and Tempered	325	590	18	14	27	22	46	21	17	37
		375	690	17	13	25	20	43	18	14	33
		420	780	15	12	22	18	39	15	12	29
		470	880	13	11	19	15	35	12	10	25
Alloy	Oil hardened and Tempered	410	590	18	14	48	41	70	27	22	46
		460	690	17	13	46	40	69	25	20	43
		590	780	15	12	43	37	66	23	19	41
		685	880	13	10	39	33	61	21	16	37
		785	980	12	8	35	29	56	18	14	33
		885	1080	11	7	29	25	50	15	12	29

$t$  = thickness of the test piece

NOTE. Circumferential test pieces from rim forgings are to give longitudinal properties.

Intermediate values may be obtained by interpolation.



When the diameter of the finished item exceeds 500 mm at least two hardness tests are to be made on each forging at positions diametrically opposite on the portion where the teeth will be cut. When the length of this portion exceeds 500 mm two tests are to be made at each end.

When the diameter of the finished item is 1000 mm or more, at least four hardness tests are to be made. These tests are to be spaced at equal distances round the circumference and this distance is not to exceed 1000 mm. When the width of the face on which the teeth will be cut exceeds 500 mm tests are to be made at each end.

(d) The difference between the highest and lowest value is not to exceed the equivalent of 20 Brinell numbers when the minimum specified tensile strength does not exceed 590 N/mm<sup>2</sup> or 30 Brinell numbers when the minimum specified tensile strength is more than 590 N/mm<sup>2</sup>.

(e) On case hardened, nitrided or induction hardened components hardness tests are to be made on the teeth when surface hardening and grinding has been completed. The results are to comply with the approved values.

#### *Sulphur Prints*

(f) On forgings with integral journals and on pinion sleeves sulphur prints are to be taken over the whole surface and ends of the toothed portion.

On forgings for gear wheels and rims sulphur prints are to be taken from one of the end faces. At the discretion of the Surveyor additional prints may be requested from selected areas on the exterior surface.

When a system of batch testing is being employed the number of sulphur prints to be taken from each batch is to be agreed.

#### *Magnetic Crack Detection*

(g) The teeth of all components which have been case hardened, nitrided or induction hardened are to be examined by magnetic particle methods. This may be requested as a supplementary test on other items.

When current flow methods are used for magnetization, particular care must be taken to avoid damaging the hardened surfaces by contact with the probes.

#### *Depth of Hardened Zone*

(h) On gear forgings where the teeth have been case hardened, nitrided or induction hardened additional test pieces may require to be processed with the forgings and subsequently sectioned to determine the depth of the hardened zone. These tests are to be carried out at the

discretion of the Surveyor and for induction or case hardened gearing the depth of the hardened zone is to be in accordance with the approved specification or as otherwise agreed. For nitrided gearing the full depth of the hardened zone, i.e. depth to core hardness, is not to be less than 0,5 mm and the hardness at a depth of 0,25 mm is not to be less than 500 D.P.N. See 621.

#### **Repair of Defects**

628 The repair of defects by welding is not permitted.

#### **Identification**

629 Forgings are to be identified in accordance with Q 109.

#### **Documentation**

630 The manufacturer is to supply the information detailed in Q 110.

### FERRITIC STEEL FORGINGS FOR TURBINES, COMPRESSORS AND TURBINE DRIVEN GENERATORS

#### **Scope**

631 Ferritic steel forgings for turbine rotors, discs and spindles, turbine driven generator rotors and compressor rotors are to be manufactured and tested in accordance with the requirements of this Section and the relevant parts of Q 1 and Q 2.

Orders and drawings for rotor forgings are to state whether the rotor is intended for propulsion or auxiliary machinery and the shaft power of auxiliary turbines. In the case of a rotor which is to be tested for thermal stability the maximum operating temperature and the proposed test temperature are also to be stated.

Where small and identical forgings are produced in large quantities, the Surveyor may adopt an alternative system of quality control provided it is approved and the required standard of inspection is maintained by the firm.

#### **Manufacture**

632 Forgings are to be manufactured in accordance with the requirements of 602 except that for rotor forgings the sectional area of any part (as forged) is not to exceed one half of the average sectional area of the ingot. Where an upsetting operation is included in the manufacturing procedure the above requirement is to apply to the sectional area of the upset bloom and not to the ingot.



**Chemical Composition**

633 The forgings may be made of carbon or alloy steel. For forgings in carbon steel the chemical composition is to comply with the following:—

Carbon	0,45% max.
Silicon	0,15 to 0,45%
Manganese	0,40% min.
Sulphur	0,050% max.
Phosphorus	0,050% max.

Where mechanical tests are required from forgings in either the radial or the tangential direction the sulphur and the phosphorus contents of the steel are not to exceed 0,040 per cent each.

Specifications of alloy steel forgings giving the proposed chemical composition, heat treatment and mechanical properties are to be submitted for approval with the plans of the components.

When it is proposed to use rotors of welded construction the compositions of the steels for the forgings are to be submitted for special consideration. These are to comply with the above limits of composition except that generally the carbon content is not to exceed 0,25 per cent.

**Heat Treatment**

634 Forgings are to be supplied in the heat treated condition and the thermal treatment at all stages is to be such as to avoid the formation of hair-line cracks. At a suitable stage of manufacture the forgings are to be reheated above the upper critical point to refine the grain, cooled in an approved manner and then tempered to produce the desired mechanical properties.

Where forgings receive their main heat treatment before machining they are to be stress relieved after rough machining. Forgings heat treated in the rough machined condition need not be stress relieved provided that they have been slowly cooled from the tempering temperature.

The tempering and stress relieving temperatures are to be not less than 550°C in the case of carbon steels and 600°C in the case of alloy steels. The holding times and subsequent cooling rates are to be such that the forging in its final condition is free from harmful residual stresses.

If forgings are stress relieved after the mechanical tests have been taken the temperature used for this treatment is to be at least 20degC lower than the temperature previously used for tempering and the forgings are subsequently to be cooled at approximately the same rate as was used for cooling after tempering.

Details of the proposed heat treatment for rotors of welded construction are to be submitted for approval.

**Test Material**

635 At least one longitudinal tensile and one bend test piece are to be taken to represent the material of each forging (or multiple forging) excluding discs. In the case of forgings (or multiple forgings) exceeding both 3 tonnes in weight and 2 m in length not less than one tensile and one cold bend test are to be taken from each end of each forging (or multiple forging) (see Fig. Q 6.5).

For rotor forgings of all main propulsion machinery and of auxiliary turbines exceeding 1100 kW tangential and, where dimensions permit, radial tensile and bend tests are also to be taken from the end of the body corresponding to the top end of the ingot (see Fig. Q 6.5).

For each turbine disc, at least one tensile and one bend test piece are to be cut in a tangential direction from material at the hub (see Fig. Q 6.6).

For this purpose, sufficient test material is to be left on each forging and is not to be removed until heat treatment has been completed except for stress relieving after rough machining as detailed in 634. In this connection a thermal stability test does not form part of the heat treatment of a turbine forging. Any excess test material is not to be completely severed from a forging until all the mechanical tests have been completed with satisfactory results.

Where a number of small forgings are made from one cast of steel and heat treated together in one furnace then a system of batch testing may be adopted. The number of tests required and the method of providing the test material is to be agreed with the Surveyor.

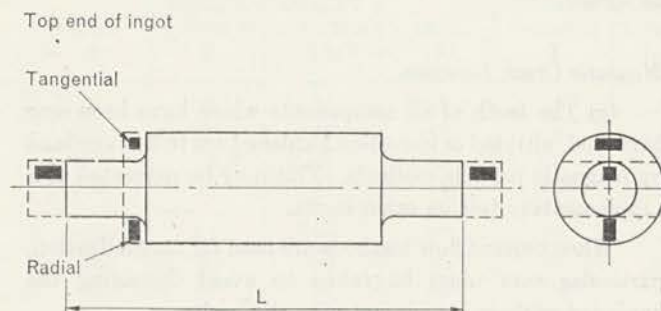


FIG. Q 6.5 ROTOR FORGINGS

Two sets of longitudinal test pieces are required only when the length  $L$  exceeds 2 m and the weight exceeds 3 tonnes. Tangential and, where dimensions permit, radial test pieces from the body are required from rotor forgings for main propulsion machinery and for auxiliary turbines exceeding 1100 kW.



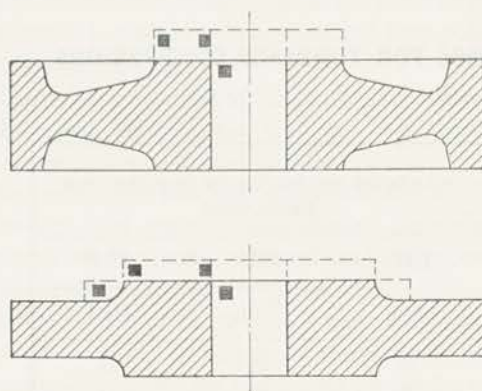


FIG. Q 6.6 TURBINE DISCS

Alternative positions for test pieces.

The dimensions of the tensile test pieces are to comply with Q 2 and they are to have a diameter of not less than 14 mm except that if necessary the tangential and radial test pieces may be of smaller diameter, in all cases these should be as large as possible and of standard proportions.

Bend test pieces are to be machined to 20 mm by 10 mm in accordance with the subsidiary test piece defined in Q 206.

#### Mechanical Properties

**636** The tensile strength of the forging is to comply with the range specified on the order. For carbon and carbon-manganese steel forgings the specified range of tensile strength is not to exceed 100 N/mm<sup>2</sup> (10 kgf/mm<sup>2</sup>) within the general limits of 440 and 690 N/mm<sup>2</sup>. For alloy steel rotor forgings the specified range is not to exceed 150 N/mm<sup>2</sup> (15 kgf/mm<sup>2</sup>) within the general limits of 440 and 930 N/mm<sup>2</sup>. For discs and other alloy steel forgings the specified range is not to exceed 150 N/mm<sup>2</sup> (15 kgf/mm<sup>2</sup>) within the general limits of 440 and 1130 N/mm<sup>2</sup>.

When it is proposed to use a steel of higher tensile strength full details are to be submitted for approval.

The yield stress, percentage elongation and percentage reduction of area are to comply with the requirements of Table Q 6.5 appropriate to the specified minimum tensile strength of the steel.

The minimum angles and maximum diameters of formers for the bend tests are given in Table Q 6.5.

#### Inspection

**637** (a) The Surveyor is to examine each forging before final acceptance at the forge.

(b) The forgemaster is to carry out an ultrasonic test on each forging and is to provide the Surveyor with a signed statement that such inspection has not revealed any significant internal defects.

(c) The end faces of the body of rotor forgings are to be machined to a fine smooth finish for visual and magnetic particle examination.

The end faces of the boss and the bore surface of each turbine disc are to be machined to a smooth finish and examined by a suitable method of magnetic crack detection.

(d) Rotor forgings for propulsion machinery and for auxiliary turbines exceeding 1100 kW are to be hollow bored for internal examination. The surface of the bore is to have a fine smooth finish and it is to be examined by means of an optical instrument of suitable magnification. Where the bore size permits, magnetic particle examination is also to be carried out. These examinations are to be confirmed by the Surveyor. Alternatively, an approved method of ultrasonic examination may be accepted instead of hollow boring. Details of the proposed method of ultrasonic examination are to be submitted for special consideration.

#### Thermal Stability Test

(e) Thermal stability tests after heat treatment and rough machining of the turbine rotors referred to in H 807 are to be undertaken in properly constructed furnaces, using accurate and reliable measuring equipment. Each test is to be carried out in accordance with the following recommended procedure:—

- (i) Five bands are to be machined concentric with the axis of rotation. Two of these are to be reference bands and are to be positioned at or near the locations of the bearings. The remaining three bands are to be test bands located one as near as possible to the mid-length, and the other two near each end of the body. Where the length of a rotor is such that five bands cannot be provided, alternative proposals are to be submitted to the Surveyor for his approval.
- (ii) Four positions, 90° apart, are to be stamped A, B, C and D, on the coupling end of the rotor.
- (iii) The whole of the body and as much of the shaft at either end as will include the positions of the glands are to be enclosed in the furnace. In the case of a rotor having an overhung astern wheel, the astern wheel is also to be

TABLE Q 6.5

**MECHANICAL PROPERTIES OF FERRITIC STEEL FORGINGS FOR TURBINES, COMPRESSORS  
AND GENERATORS**

SPECIFIED MINIMUM TENSILE STRENGTH	MINIMUM PERCENTAGE ELONGATION FOR GAUGE LENGTH OF $5,65\sqrt{S_o}$			MAXIMUM DIAMETER OF FORMER FOR BEND TEST		
				180°	150°	120°
N/mm <sup>2</sup>	Long.	Tan.	Rad.	Long.	Tan.	Rad.
440	24	20	17	2t	2t	2t
490	23	19	16	2t	2t	2t
540	22	17	15	$2\frac{2}{3}t$	$2\frac{2}{3}t$	$2\frac{2}{3}t$
590	19	16	14	4t	4t	4t
690	17	14	12	4t	4t	4t
780	16	12	10	4t	4t	—
880	15	11	—	6t	6t	—
980	14	10	—	6t	6t	—
Yield Stress	Not less than 50% of the actual tensile strength for material in the normalized and tempered condition. Not less than 60% of the actual tensile strength for low alloy material in the quenched and tempered condition.					
Reduction of area	Not less than 35% for longitudinal tests. Not less than 30% for tangential tests. Not less than 20% for radial tests.					

Long. — For longitudinal tests  
 Tan. — For tangential tests  
 Rad. — For radial tests  
 t — Thickness of test piece.

Intermediate values are to be obtained by interpolation.

enclosed in the furnace during the first test (see H 807).

- (iv) The rotor is to be rotated at a uniform and very slow speed.
- (v) The deflections at all bands are to be recorded at the A, B, C and D positions. Initial cold readings are to be taken prior to heating.
- (vi) The rotor is to be heated uniformly and slowly. Temperatures are to be recorded continuously at the surface of the rotor and if practicable in the bore at the mid-length of the body. Under no circumstances is the surface temperature to exceed the temperature at which the rotor was tempered. During heating the rate of rise of temperature is to be such as to avoid excessive temperature gradients in the rotor.

(vii) The maximum or holding temperature is to be not less than 28degC above the maximum operating temperature of the rotor. For the purposes of the test the holding period is to start when the rotor has attained a uniform and specified temperature. The rotor is to be held under the specified temperature conditions until not less than three consecutive hourly readings of deflections show the radial eccentricity to be constant within 0,006 mm on all test bands.

(viii) The turbine rotor is to be rotated during cooling until the temperature is not more than 100°C. The rate of cooling is to be such as to avoid excessive temperature gradients in the rotor.

(ix) Final cold readings are to be taken.



The movements of the axis of the rotor in relation to the reference bands are to be determined from polar plots of the deflection readings.

The radial movement of the shaft axis as determined by the difference between the final hot and the final cold movements is not to exceed 0,025 mm on any one band.

As verification that test equipment and conditions are satisfactory it is required that similar determinations of differences between initial cold and final cold movements do not exceed 0,025 mm on any one band.

If the results of the test on a rotor fail to meet either or both of the above requirements, the test may be repeated if requested by the maker and agreed by the Surveyor.

In the case of a rotor failing to meet the requirements of a thermal stability test, the rotor is deemed unacceptable. Proposals for the rectification of thermal instability of a rough machined rotor are to be submitted for special consideration.

#### Repair of Defects

638 The repair of defects by welding is not permitted.

#### Identification

639 Forgings are to be identified in accordance with Q 109.

#### Documentation

640 The manufacturer is to supply the information detailed in Q 110 and a certificate of ultrasonic examination as required by 637(b).

### FORGINGS FOR BOILERS AND PRESSURE VESSELS

#### Scope

641 Forged seamless drums, headers and other forgings intended for boilers and pressure vessels are to be manufactured and tested in accordance with the requirements of this Section and the relevant parts of Q 1 and Q 2. For pressure vessels containing radioactive materials or gases additional requirements may be specified.

Provision is made for three categories of forgings which differ mainly in respect of testing procedure and are intended for the following uses:—

- |             |                                                                                                                           |
|-------------|---------------------------------------------------------------------------------------------------------------------------|
| Category I  | Where design is based on guaranteed values for elevated temperature properties.                                           |
| Category II | Where design is based on nominal values for elevated temperature properties which are not required to be proved by tests. |

- |              |                                                                                                                                                                                                                                    |
|--------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Category III | For pressure vessels intended for special low temperature service where the steel is to have guaranteed low temperature Charpy V-notch impact properties. In this case the proposed specification is to be submitted for approval. |
|--------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

Alternative specifications may be accepted provided they give reasonable equivalents to the requirements of this Section.

Where small and identical forgings are produced in large quantities, the Surveyor may adopt an alternative system of quality control provided it is approved and the required standard of inspection is maintained by the manufacturer.

#### Manufacture

642 Forgings are to be manufactured in accordance with the requirements of 602.

Seamless drums and headers are to be forged from ingots or forged blooms which have been punched, bored or trepanned. Alternatively, where specially approved, hollow cast ingots may be used. The wall of the hollow ingot or bloom is to be reduced in thickness by at least two-thirds during subsequent forgings. Other proposals are to be submitted for approval.

#### Chemical Composition

643 For Categories I or II the chemical composition of the steel is to comply with the requirements of Table Q 3.1 except that the steel is to be killed.

For Category III the chemical composition is to comply with the requirements of the approved specification.

#### Heat Treatment

644 All carbon and carbon-manganese steel forgings are to be normalized or normalized and tempered. All alloy steel forgings are to be normalized and tempered.

If required by the Surveyors or by the fabricators test material may be given a simulated stress relieving heat treatment prior to the preparation of the test pieces. This has to be stated on the order together with agreed details of the simulated heat treatment and the mechanical properties which can be expected.

#### Test Material

645 (a) Category I. Tensile and bend tests are to be made at ambient temperature on material from each forging.

On seamless drums and headers, which are initially forged with open ends, test material is to be provided at each end of each forging. On seamless drums or headers,



forged with one solid end, test material is to be provided at the open end only. Except where the ends are to be subsequently closed by forging, the test material is not to be removed until heat treatment has been completed. Where the ends are to be closed, rings of test material are to be cut off prior to the closing operation and are to be heat treated with the finished forging. In all cases the test pieces are to be cut in a circumferential direction.

In addition to the tests at ambient temperature, one tensile test at elevated temperature is to be made to represent each drum or header forging. This test piece is to be taken from the end which gave the lower tensile value at ambient temperature.

For forgings other than seamless drums and headers test material is to be provided for tensile and bend tests at ambient temperature in accordance with 605. In addition, one tensile test at elevated temperature is to be made from each forging or for each batch of forgings.

Tensile tests at elevated temperature are not required when:—

- (i) the reference test temperature is 100°C or less,
- (ii) the specified minimum value of the 0,2 per cent proof stress value at the reference test temperature is higher than the corresponding stress-to-rupture value,
- (iii) the actual tensile strength at ambient temperature exceeds by at least 40 N/mm<sup>2</sup> (4 kgf/mm<sup>2</sup>) the minimum specified tensile strength. This applies only to carbon and carbon-manganese steels.

(b) Category II. Test material is to be provided for the tests at ambient temperature specified for Category I. Tests at elevated temperatures are not required.

(c) Category III. On seamless drums and headers test material is to be provided for the tests at ambient temperature specified for Category I. In addition, three Charpy V-notch test pieces are to be prepared from each end except for drums or headers forged with one solid end, when impact tests are required from the open end only.

For forgings other than seamless drums and headers test material is to be provided for the tests at ambient temperature specified for Category I and, in addition, Charpy V-notch test pieces are to be taken from each forging or from each batch of forgings when specified.

(d) The dimensions of the tensile test pieces are to comply with the requirements of Q 2. Test pieces for ambient temperature tests are to have a diameter of not

less than 14 mm unless the thickness of the test material is insufficient, in which case the diameter is to be as large as possible.

Bend test pieces are to be in accordance with Q 2.

Charpy V-notch test pieces are to be machined in accordance with the dimensions given in Q 2.

### Mechanical Tests

**646** (a) Category I. The results of all tensile tests are to comply with the values given in Table Q 6.6. The lower yield or 0,2 per cent proof stress values at elevated temperatures are to be determined at the reference test temperature given in the order and are to comply with the values given in the above Table or as otherwise agreed with the manufacturer.

Bend test pieces are to withstand being bent through an angle of 180° round a former having a diameter not greater than that specified in Table Q 6.6.

Stress rupture values for design purposes are given in Table Q 3.5.

(b) Category II. The results of all tensile tests at ambient temperature are to comply with the values given in Table Q 6.7.

Bend test pieces are to withstand being bent through an angle of 180° round a former having a diameter not greater than that specified in Table Q 6.7.

For design purposes nominal values of the lower yield or 0,2 per cent proof stress at elevated temperatures are given in Table Q 6.7 and stress rupture values in Table Q 3.5.

(c) Category III. The results of all tensile, bend and impact tests are to comply with the approved specification. The Charpy V-notch tests are to be made at or below the approved reference test temperature.

### Inspection

**647** The Surveyor is to examine each forging before final acceptance at the forge.

On seamless drums sulphur prints may be requested to demonstrate that sufficient ingot discard has been taken.

When a number of separate small forgings are tested as a batch, the hardness of each forging is to be determined including those from which material is to be cut for the provision of tensile, bend and Charpy test pieces. The hardness of the forgings are to comply with a specification approved by the Surveyor before manufacture of the forgings. The Surveyor is to satisfy himself that the inspection procedure for surface condition and soundness adopted by the manufacturer is adequate.



**TABLE Q 6.6**  
**MECHANICAL PROPERTIES OF FORGINGS FOR BOILERS AND PRESSURE VESSELS CATEGORY I**

GRADE OF STEEL	YIELD STRESS MINIMUM N/mm <sup>2</sup>	TENSILE STRENGTH N/mm <sup>2</sup>	ELONGATION ON 5,65√S <sub>0</sub> % MINIMUM	BEND TEST MAXIMUM DIAMETER OF FORMER	MINIMUM LOWER YIELD OR 0,2% PROOF STRESS in N/mm <sup>2</sup> (=MPa)										
					100°C	150°C	200°C	250°C	300°C	350°C	400°C	450°C	500°C	550°C	600°C
Carbon and Carbon-Manganese	180	360-460	25	2t	164	154	143	136	127	119	111	107			
	205	410-510	23	2t	188	179	169	161	151	143	136	131			
	230	460-560	21	3t	213	204	193	185	176	169	161	156			
	255	510-610	20	3t	238	228	218	210	201	193	185	180			
1Cr-½Mo	230	410-510	23	3t	224	216	209	187	164	148	145	142	139		
2¼Cr-1Mo	385	540-670	18	3t	354	338	330	326	323	320	314	297	270	216	

t = thickness of bend test piece.

TABLE Q 6.7

## MECHANICAL PROPERTIES OF FORGINGS FOR BOILERS AND PRESSURE VESSELS CATEGORY II

GRADE OF STEEL	YIELD STRESS MINIMUM N/mm <sup>2</sup>	TENSILE STRENGTH N/mm <sup>2</sup>	ELONGATION ON 5,65√S <sub>0</sub> % MINIMUM	BEND TEST MAXIMUM DIAMETER OF FORMER	LOWER YIELD OR 0,2% PROOF STRESS in N/mm <sup>2</sup> (=MPa) ( <i>see</i> NOTE)											
					100°C	150°C	200°C	250°C	300°C	350°C	400°C	450°C	500°C	550°C	600°C	
Carbon and Carbon- Manganese	180	360-460	25	2t	145	142	139	126	110	94	92	92				
	205	410-510	23	2t	177	173	170	155	139	124	121	118				
	230	460-560	21	3t	206	204	199	182	167	151	142	132				
	255	510-610	20	3t	236	233	227	210	195	179	162	147				
1Cr-½Mo	230	410-510	23	3t	191	183	178	159	139	126	124	121	119			
2¼Cr-1Mo	385	540-670	18	3t	301	287	280	277	274	272	267	252	229	183		

t = thickness of bend test piece.

NOTE. The values for yield stress or 0,2 per cent proof stress at elevated temperatures are given for design purposes and do not have to be proved by test.



**Repair of Defects**

648 The repair of minor surface defects in accordance with Q 108 will be considered.

**Identification**

649 Forgings are to be identified in accordance with Q 109.

**Documentation**

650 The manufacturer is to supply the information detailed in Q 110.

**Section 7****STEEL TUBES AND PIPES****Scope**

701 (a) Boiler tubes, superheater tubes and pipes intended for use in the construction of boilers and pressure vessels are to be manufactured and tested in accordance with the requirements of this Section and the relevant parts of Q 1 and Q 2. These requirements are also applicable to pressure pipes intended for the services detailed in E 508 and for special low temperature service. Pressure pipes other than those mentioned in E 508 and having a design pressure of not less than 0.69 N/mm<sup>2</sup> (7 kgf/cm<sup>2</sup>) may be made and tested to the requirements of this Section, or alternatively, may be in accordance with an approved national specification except that forge butt welded pipes are not acceptable. (See E 508, quoted at end of this Section.)

Pressure pipes, when available in suitable sizes, may be used for the manufacture of seamless pressure vessels or headers and in such cases the requirements for forgings given in Q 643 to Q 650 would be applicable.

Provision is made for four categories which differ mainly in respect of testing procedures and are intended for the following uses:—

- |                 |                                                                                                                                                                                                               |
|-----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Category I      | Where design is based on guaranteed values for elevated temperature properties.                                                                                                                               |
| Category II     | Where design is based on nominal values for elevated temperature properties which are not required to be proved by test.                                                                                      |
| Category III(a) | For special low temperature service where the steel is required to have guaranteed low temperature Charpy V-notch impact properties. This category is not applicable to material with a thickness under 3 mm. |

Category III(b) For similar service where fine grain steels are acceptable without proving the low temperature impact properties by acceptance tests.

For Category III(a) and III(b) material, the proposed specification is to be submitted for approval.

(b) Orders should indicate the category of material required and if intended for use as boiler tubes, superheater tubes, or pressure pipes. For Categories I and III the reference test temperature is also to be given (see Q 101(c)).

(c) At the discretion of the Surveyor, a modified testing procedure may be adopted for small quantities of material. In such cases short lengths may be accepted on the manufacturer's declared chemical composition and hardness tests or other evidence of satisfactory properties.

(d) Alternatively, steel tubes or pipes which comply with national or proprietary specifications may be accepted provided these specifications give reasonable equivalence to the requirements of this Section.

**Manufacture**

702 (a) For Category I the steel is to be either silicon or aluminium killed. (See Table Q 7.1.)

For Category II any method of deoxidation may be used except that rimming steel may only be used for design temperatures not exceeding 400°C.

For Category III the method of deoxidation is to be in accordance with the approved specification.

(b) Tubes and pipes may be manufactured by any of the following methods unless one of these methods is particularly specified on the order:—

- Hot Finished Seamless,
- Cold Finished Seamless,
- Electric Resistance Welded,
- Cold Finished Electric Resistance Welded,
- Electric Fusion Welded (austenitic stainless steel only).

If rimming steel strip is used for the manufacture of electrical resistance welded tubes or pipes, the strips are to be rolled in single widths and not slit longitudinally.

For Category III the method of manufacture is to be included in the specification submitted for approval.

(c) Care is to be taken that any non-ferrous metals or their compounds coming into contact with the tubes or pipes during manufacture are not deposited so as to be harmful during subsequent fabrication and operation.



**Chemical Composition**

703 For Categories I and II the chemical composition is to comply with the requirements given in Table Q 7.1.

The chemical composition of steel for Category III is to comply with the approved specification.

**Heat Treatment**

704 For Categories I and II tubes and pipes are to be supplied in the condition detailed in Table Q 7.2.

For Category III the heat treatment is to comply with the approved specification.

**Test Material**

705 (a) Tests are to be made on straight tubes and pipes after completion of all drawing and heat treatment operations.

(b) Category I. Tubes and pipes are to be presented for test in batches. Each batch is to contain not more than 400 lengths when the outside diameter is not more than 114,3 mm, or not more than 200 lengths when the outside diameter is more than 114,3 mm.

Where heat treatment has been carried out, a batch is to consist of tubes or pipes of the same size, manufactured from the same cast of steel and subjected to the same finishing treatment in a continuous furnace or heat treated in the same furnace charge in a batch type furnace.

Where no heat treatment has been carried out, a batch is to consist of tubes or pipes of the same size manufactured from the same cast of steel and by the same process of manufacture.

At least 2 per cent of the number of lengths in each batch are to be selected at random for the preparation of tests at ambient temperature. Each boiler tube selected for test is to be subjected to tensile, flattening and expanding tests. The expanding test is to be made at each end of each sample length.

Each pressure pipe selected for test is to be subjected to tensile and flattening or bend tests.

(c) Tensile tests at elevated temperature are to be taken from each cast unless the weight of finished material is greater than 30 tonnes in which case one extra test is to be taken from each 30 tonnes or fraction thereof.

These tensile tests at elevated temperature are not required when:—

- (i) the reference test temperature is 100°C or less,
- (ii) the minimum specified value of the 0,2 per cent proof stress value at the reference test temperature is higher than the corresponding stress-to-rupture value,

(iii) the actual tensile strength at ambient temperature exceeds by at least 50 N/mm<sup>2</sup> (5 kgf/mm<sup>2</sup>) the minimum specified tensile strength. This applies only to carbon and carbon-manganese steels,

(iv) the manufacturer has obtained certification of elevated temperature proof stress values as detailed in 706(d).

(d) Category II. Tubes and pipes are to be presented for test in batches. Each batch is to contain not more than the number of lengths permitted in Category I but may consist of tubes or pipes of the same size, manufactured by the same method from material of the same specification.

Tests at ambient temperature are to be taken as for Category I. Tensile tests at elevated temperature are not required.

(e) Category III. Tubes and pipes are to be presented for test in batches and tests taken in accordance with the requirements for Category I except that tests at elevated temperatures are not required. In addition for Category III(a) material a set of three Charpy V-notch test pieces is to be taken from each batch. When the wall thickness is insufficient to permit the preparation of standard Charpy test pieces then the largest possible subsidiary test piece is to be prepared, see Q 208.

(f) All test pieces are to be prepared in accordance with the requirements of Q 2.

**Mechanical Properties**

706 (a) Category I. The results of all tensile tests are to comply with the values given in Table Q 7.3. The lower yield or 0,2 per cent proof stress values at elevated temperature are to be determined in accordance with Q 205 at the reference test temperature given in the order.

The flattening test for boiler and superheater tubes and for pressure pipes is to be carried out in accordance with Q 209. The test is to be continued until the distance between the platens, measured under load is not greater than the value given by the formula:—

$$H = \frac{t(1 + c)}{c + \frac{t}{D}}$$

where H = distance between platens, in mm,

t = specified thickness of the tube, in mm,

D = specified outside diameter of the tube, in mm,

c = a constant depending on the steel.



TABLE Q 7.1  
CHEMICAL COMPOSITION OF TUBES AND PIPES

GRADE OF STEEL	TENSILE STRESS N/mm <sup>2</sup>	METHOD OF DEOXIDATION	CHEMICAL COMPOSITION OF LADLE SAMPLES—PERCENTAGE										
			C	Si	Mn	S	P	Residual Elements					
Carbon	340–460	Silicon or aluminium killed	0,20 max.	0,10–0,35	0,40–0,90	0,050 max.	0,050 max.	Ni 0,30 max. Cr 0,25 max. Mo 0,10 max. Cu 0,30 max. Total 0,70 max.					
Category I	410–530		0,25 max.	0,10–0,35	0,40–1,00	0,050 max.	0,050 max.						
Carbon	320–440	Any method but see Note 1 for rimmed steel	0,18 max.	—	0,30–0,70	0,050 max.	0,050 max.						
Category II	340–460		0,20 max.	0,35 max.	0,30–0,90	0,050 max.	0,050 max.						
	410–530		0,25 max.	0,35 max.	0,30–1,00	0,050 max.	0,050 max.						
Low ALLOY		Silicon killed						Ni	Cr	Mo	Cu	V	Sn
1Cr– $\frac{1}{2}$ Mo	410–620		0,10–0,15	0,10–0,35	0,40–0,70	0,040 max.	0,040 max.	0,30 max.	0,70–1,10	0,45–0,65	0,25 max.	—	0,03 max.
2 $\frac{1}{2}$ Cr–1Mo	410–560		0,08–0,15	0,10–0,50	0,40–0,70	0,040 max.	0,040 max.	0,30 max.	2,00–2,50	0,90–1,20	0,25 max.	—	0,03 max.
490–690													
$\frac{1}{2}$ Cr– $\frac{1}{2}$ Mo– $\frac{1}{4}$ V	460–610		0,15 max.	0,10–0,35	0,40–0,70	0,040 max.	0,040 max.	0,30 max.	0,25–0,50	0,50–0,70	0,25 max.	0,22–0,30	0,03 max.
High ALLOY													
17–13–Mo	510–700		0,04–0,09	0,75 max.	1,00–2,00	0,030 max.	0,040 max.	12,0–14,0	16,0–17,5	2,00–2,75	—	—	—
18–12–Nb (Note 2)	510–700		0,04–0,09	0,20–0,80	0,50–2,00	0,030 max.	0,040 max.	11,0–13,0	17,0–19,0	—	—	—	—
18–10–Ti (Note 3)	510–700		0,04–0,09	0,20–0,80	0,50–2,00	0,030 max.	0,040 max.	9,0–13,0	17,0–20,0	—	—	—	—

NOTES. 1. Rimmed steel is only to be used for applications where the design temperature does not exceed 400°C.

2. Niobium+Tantalum. Minimum 10×% Carbon. Maximum 1,10%.

3. Titanium. Minimum 4×% Carbon. Maximum 0,60%.

**TABLE Q 7.2**  
**HEAT TREATMENT OF TUBES AND PIPES**

GRADE OF STEEL				CONDITION OF SUPPLY						CATEGORY
<b>CARBON</b>										
Hot Finished Seamless...	...	...	...	As rolled or ... (Note 1)						I & II
				Normalized 880/920°C ... (Note 2)						I & II
Cold Finished Seamless	...	...	...	Annealed or ... (Note 3)						II
				Normalized 880/920°C ... (Note 2)						I & II
Electric Resistance Welded	...	...	...	Normalized 880/920°C ... (Note 2)						I & II
Cold Finished E.R.W.	...	...	...	Normalized 880/920°C ... (Note 2)						I & II
<b>ALLOY STEEL</b>										
1Cr- $\frac{1}{2}$ Mo	...	...	...	Normalized 900/960°C	Tempered 640/690°C	...	...	...	...	I & II
2 $\frac{1}{4}$ Cr-1Mo	...	...	...	Annealed 920/960°C or ... (Note 4)						I & II
				Normalized 920/960°C Tempered 650/750°C ... (Note 5)						I & II
$\frac{1}{2}$ Cr- $\frac{1}{2}$ Mo- $\frac{1}{4}$ V	...	...	...	Normalized 950/980°C	Tempered 660/710°C	...	...	...	...	I & II
17-13-Mo	...	...	...	Solution treated 1 050/1 100°C ...						I & II
18-12-Nb	...	...	...	Solution treated 1 070/1 120°C ...						I & II
18-10-Ti	...	...	...	Solution treated 1 090/1 140°C ...						I & II

## NOTES

1. Provided the hot finishing temperature is sufficiently high to soften the material.

2. At the option of the manufacturer tubes and pipes may also be tempered after normalizing.

3. Annealed tubes and pipes are only to be used for applications where the design temperature does not exceed 400°C.

4. Where the cooling rate from annealing temperature exceeds 100degC per hour, the material is to be tempered at 650/700°C.

5. For tempering temperatures of 720°C or higher, the time above this temperature is not to exceed 30 minutes.

6. Time at tempering temperature is to be not less than 3 hours.



<i>Steel</i>	<i>Values for c</i>
Carbon 320/440	0,09
340/460	0,09
410/530	0,07
1Cr $\frac{1}{2}$ Mo	0,08
2 $\frac{1}{4}$ Cr 1Mo	0,08
$\frac{1}{2}$ Cr $\frac{1}{2}$ Mo $\frac{1}{4}$ V	0,08
17, 13 Mo	0,09
18, 12 Nb	0,09
18, 10 Ti	0,09

For pressure pipes, bend tests may be taken as an alternative for flattening tests and are to be carried out in accordance with Q 207. The test pieces are to withstand being bent through an angle of 180° round a former having a diameter not greater than that specified in Table Q 7.3.

The drift expanding test specified for boiler and superheater tubes is to be carried out in accordance with Q 210. The test is to be continued until the increase in outside diameter is not less than the following values.

<i>Outside diameter</i>	<i>Minimum increase per cent</i>
Up to and including 63,5 mm	17
Over 63,5 mm	11

Stress rupture values for design purposes are given in Table Q 7.5.

(b) Category II. The results of tensile tests at ambient temperature are to comply with the values given in Table Q 7.4. For design purposes, nominal values of the yield or 0,2 per cent proof stress at elevated temperatures are given in Table Q 7.4. Stress rupture values are given in Table Q 7.5.

Expanding and flattening or bend tests are to be carried out as specified for Category I, the maximum diameter of the former for the bend test is given in Table Q 7.4.

(c) Category III. The Charpy V-notch tests are to be made at or below the reference test temperature given in the order. The results of the tensile, Charpy V-notch and flattening or bend tests are to comply with the approved specification.

#### *Certification of Lower Yield or 0,2 per cent Proof Stress Values at Elevated Temperatures*

(d) For Category I material or other approved grades, as an alternative to taking tensile tests at elevated tempera-

ture in accordance with 705(c), individual manufacturers may submit for analysis and approval comprehensive test data for a specific grade of steel to demonstrate the lower yield or 0,2 per cent proof stress values at elevated temperatures which can be consistently obtained. This data will be assessed on a statistical basis to determine the 95 per cent lower confidence limit. When a manufacturer is approved on this basis routine tensile tests at elevated temperature will not be required except for periodic check tests at the discretion of the Surveyors.

Manufacturers requiring this form of certification are to submit the following information and test data from at least 45 batches taken from not less than 10 different casts for each grade of steel:—

- (1) Ladle analysis including residual elements.
- (2) Method of deoxidation.
- (3) Method of manufacture.
- (4) Details of heat treatment.
- (5) Results of tensile tests at ambient temperature:—  
Yield stress, tensile strength and percentage elongation.
- (6) Results of tensile tests at elevated temperatures:—  
Lower yield or 0,2 per cent proof stress values at 100, 150, 200, 250, 300, 350, 400, 450°C or higher if appropriate for the grade of steel being tested.
- (7) Thickness of tubes or pipes.

The test data are to be representative of the tensile range specified for the grade and also the range of thickness which will be manufactured. For carbon and carbon-manganese steels where there is an overlap in the specified tensile strength range, data submitted for one grade may also be considered for adjacent grades provided the properties at ambient temperature comply with the appropriate tensile strength range.

#### **Inspection**

**707** (a) The tubes and pipes are to be straight, smooth and cylindrical within practical limits. The ends are to be cut square with the axis and are to be ground where necessary to facilitate examination.

They are to be presented for examination under adequate conditions of lighting and are to be examined internally and externally.

(b) In the case of welded tube or pipe the manufacturer is to employ suitable non-destructive methods for the quality control of the weld. It is preferred that this examination is carried out on a continuous basis.

*Dimensional Tolerances of Pressure Pipes*

(c) The thickness and diameter of each pressure pipe is to be within the following tolerances:—

*(i) Hot Finished Seamless*

THICKNESS	RATIO OF THICKNESS TO OUTSIDE DIAMETER		TOLERANCE
	up to and including 3%		$\pm 15\%$
	over 3% and up to 10%		$\pm 12,5\%$
	over 10%	up to and including 168,3 mm o.d. over 168,3 mm o.d.	$\pm 12,5\%$ $\pm 10\%$
OUTSIDE DIAMETER	Tolerance $\pm 1\%$ with a minimum of $\pm 0,5$ mm		

*(ii) Cold Finished Seamless*

SIZE	Up to and including 219,1 mm o.d.	over 204 mm i.d.
TOLERANCE ON THICKNESS	$\pm 10\%$	up to and including 6,3 mm thick $+15\%$ $-0\%$
		over 6,3 mm thick $+10\%$ $-0\%$
TOLERANCE ON INSIDE DIAMETER	—	$+0,8$ mm $-1,6$ mm
TOLERANCE ON OUTSIDE DIAMETER	$\pm 1\%$	—

*(iii) Electric Resistance Welded*

THICKNESS (except at weld)	TOLERANCE
Up to and including 139,7 mm o.d.	$\pm 7,5\%$
Over 139,7 mm o.d.	$\pm 10\%$
OUTSIDE DIAMETER	$\pm 1\%$ with a minimum of $\pm 0,5$ mm

NOTE. At the weld the external fin is to be removed completely, i.e. flush with the outside surface of the pipe. Where practicable, the internal fin is to be removed throughout the length of the pipe so that its maximum height shall not exceed 8% of the specified thickness or 0,25 mm, whichever is the greater.



*Dimensional Tolerances of Boiler and Superheater Tubes*

(d) The thickness and diameter of each tube is to be within the following tolerances which apply only to plain tubes:—

(i) *Hot Finished Seamless*

THICKNESS	Tolerance $\pm 12,5\%$
OUTSIDE DIAMETER	$\pm 1\%$ with a minimum of $\pm 0,5$ mm

(ii) *Cold Finished Seamless: Carbon and Low Alloy Steel: Cold Finished Electric Resistance Welded: Carbon and Low Alloy Steel*

THICKNESS	Tolerance $\pm 7,5\%$
OUTSIDE DIAMETER	$\pm 0,5\%$ with a minimum of $\pm 0,1$ mm

(iii) *Cold Finished Seamless: Austenitic Steel*

THICKNESS	TOLERANCE
up to and including 3,2 mm	$\pm 10\%$
over 3,2 mm	$\pm 7,5\%$
OUTSIDE DIAMETER	$\pm 0,5\%$ with a minimum of $\pm 0,15$ mm

(iv) *Electric Resistance Welded*

THICKNESS (except at weld)	TOLERANCE
up to and including 3,2 mm	$\pm 10\%$
over 3,2 mm	$\pm 7,5\%$
OUTSIDE DIAMETER	$\pm 0,75\%$ with a minimum of $\pm 0,3$ mm

NOTE. At the weld the external fin is to be removed completely, i.e. flush with the outside surface of the tube. The internal fin is also to be removed throughout the length of the tube so that the maximum height of fin is not greater than 0,25 mm.

Table Q 7.3

TABLE Q 7.3  
MECHANICAL PROPERTIES OF TUBES AND PIPES CATEGORY I

GRADE OF STEEL	YIELD STRESS MINIMUM N/mm <sup>2</sup>	TENSILE STRENGTH N/mm <sup>2</sup>	ELONGATION ON 5,65√S <sub>0</sub> % MINIMUM	BEND TEST MAXIMUM DIAMETER OF FORMER	MINIMUM LOWER YIELD STRESS OR 0,2% PROOF STRESS, N/mm <sup>2</sup> (=MPa)										
					100°C	150°C	200°C	250°C	300°C	350°C	400°C	450°C	500°C	550°C	600°C
Carbon	210	340-460	27	3t	182	180	177	167	145	129	118	115			
Carbon	245	410-530	23	4t	201	198	190	179	158	143	137	131			
1Cr-½Mo	230	410-620	17	4t	225	216	209	187	164	148	145	142	139		
2¼Cr-1Mo (Note 1)	230	410-560	20	4t	196	178	153	148	143	137	132	129	126	121	
2¼Cr-1Mo (Note 2)	265	490-690	16	4t	253	250	245	235	226	216	206	196	186		
½Cr-½Mo-¼V	295	460-610	20	4t	253	250	245	235	226	216	206	196	186		
17-13-Mo	185	510-700	30	3t											
18-12-Nb	205	510-700	30	3t											
18-10-Ti	165	510-700	30	3t											

t = thickness of bend test piece.

- NOTES. 1. Annealed condition.  
2. Normalized and tempered condition.



TABLE Q 7.4

## MECHANICAL PROPERTIES OF TUBES AND PIPES CATEGORY II

GRADE OF STEEL	YIELD STRESS MINIMUM N/mm <sup>2</sup>	TENSILE STRENGTH N/mm <sup>2</sup>	ELONGATION ON 5,65√S <sub>0</sub> % MINIMUM	BEND TEST MAXIMUM DIAMETER OF FORMER	LOWER YIELD STRESS OR 0,2% PROOF STRESS, N/mm <sup>2</sup> (=MPa) (NOTE 1)										
					100°C	150°C	200°C	250°C	300°C	350°C	400°C	450°C	500°C	550°C	600°C
Carbon	160	320-440	27	3t	124	119	115	105	90	72	71	70			
	175	340-460	27	3t	133	130	127	115	100	82	80	80			
	210	410-530	23	4t	177	173	170	155	139	124	121	118			
1Cr-½Mo	220	410-620	17	4t	191	183	178	159	139	126	124	121	119		
2¼Cr-1Mo (Note 2)	210	410-560	20	4t	167	151	130	126	122	117	113	110	107	102	
2¼Cr-1Mo (Note 3)	245	490-690	16	4t	215	213	209	200	191	183	174	167	158		
½Cr-½Mo-¼V	275	460-610	20	4t	215	213	209	200	191	183	174	167	158		
17-13-Mo	185	510-700	30	3t											
18-12-Nb	205	510-700	30	3t											
18-10-Ti	165	510-700	30	3t											

t = thickness of bend test piece.

- NOTES. 1. The values for lower yield stress or 0,2 per cent proof stress at elevated temperatures are given for design purposes and do not have to be proved by tests.
2. Annealed condition.
3. Normalized and tempered condition.

TABLE Q 7.5

AVERAGE VALUES FOR STRESS TO RUPTURE IN 100 000 hours, CATEGORIES I AND II in N/mm<sup>2</sup> (=MPa)

TEMPERATURE °C	CARBON STEEL	ALLOY STEELS					
		1Cr- $\frac{1}{2}$ Mo	2 $\frac{1}{4}$ Cr-1Mo	$\frac{1}{2}$ Cr- $\frac{1}{2}$ Mo- $\frac{1}{4}$ V	17-13-Mo	18-12-Nb	18-10-Ti
350	211						
360	193						
370	176						
380	157						
390	140						
400	123						
410	106						
420	92						
430	81						
440	72						
450	64	314		325			
460	56	279		293			
470	49	245		264			
480	43	212	210	236			
490	37	179	188	210			
500	32	148	169	185			
510		122	148	162			
520		99	129	139			
530		78	113	119			
540		62	97	100			
550		49	83	86	204	158	191
560		40	71	73	188	143	178
570		31	60	64	173	129	165
580		24	51	54	158	116	153
590			43		142	103	140
600			37		128	91	128
610					113	80	116
620					102	71	103
630					89	62	91
640					78	54	80
650					70	46	71
660					59	40	60
670					52	34	51
680					45	29	
690						25	
700						20	
710						17	
720							



**Hydraulic Tests**

(e) Each boiler or superheater tube and each pressure pipe is to be subjected to a hydraulic test at the manufacturer's works. The test pressure is to be maintained for sufficient time to permit proof and inspection. Unless otherwise agreed, the manufacturer's certificate of satisfactory hydraulic test may be accepted.

The test pressure is to be 1,5 times the design pressure or  $6,86 \text{ N/mm}^2$  ( $70 \text{ kgf/cm}^2$ ) whichever is the greater. The test pressure is not, however, to exceed that calculated from the formula

$$P = \frac{2st}{D} \quad \left( P = \frac{200st}{D} \right)$$

where  $P$  = test pressure, in  $\text{N/mm}^2$  ( $\text{kgf/cm}^2$ ),

$D$  = nominal outside diameter, in mm,

$t$  = nominal wall thickness, in mm,

$s$  =  $0,40 \times$  minimum specified tensile strength, in  $\text{N/mm}^2$  ( $\text{kgf/mm}^2$ ).

**Repair of Defects**

708 The repair of minor defects by welding can be accepted subject to compliance with the requirements of Q 108.

**Identification**

709 Tubes and pipes are to be identified in accordance with Q 109. It is recommended that hard stamping be restricted to the end face but may be accepted in other positions in accordance with national standards and practice.

**Documentation**

710 The manufacturer is to supply the information detailed in Q 110.

**Extract from Chapter E for reference****Steel Pipes**

E 508 Steel pipes for a design pressure exceeding  $1,72 \text{ N/mm}^2$  ( $17,5 \text{ kgf/cm}^2$ ) or a temperature exceeding  $220^\circ\text{C}$ , and all feed pipes and pressure pipes conveying heated oil are to be manufactured and tested in accordance with the requirements of Q 7. Where it is proposed to use materials for pipes other than shown in Q 7, the information called for in E 511 (a) is to be submitted for consideration.

**Section 8****CAST IRON CRANKSHAFTS****General**

801 Cast iron crankshafts are to be cast at an approved foundry to an approved material specification, and to approved manufacturing and inspection procedures. The inspection procedure will include the approved size, form and location of the test blocks on the crankshaft castings.

**Grades of Cast Iron**

802 Any suitable grade of flake graphite, low alloy, acicular or spheroidal or nodular graphite cast iron may be used for crankshafts. The minimum tensile strength of the particular grade of cast iron, corresponding to the section of the crankshaft, is not to be less than that detailed in the approved Specification. (See H 202, also N 330 and N 331.)

**Process of Manufacture**

803 The raw materials of a charge such as pig iron, return scrap and scrap steel, are to be specially selected. The melt is to be closely controlled particularly with regard to temperature, time and composition when inoculated irons are being produced. Where such irons are made, the casting temperature and the time between completion of the inoculation and finished pouring of the castings are to be recorded. The records are to be available to the Surveyor at any time.

The Surveyor is to be provided with a statement giving the chemical composition of the material used for each crankshaft or batch of crankshafts.

**Heat Treatment**

804 In general, crankshaft castings other than those which are fully annealed, normalized or oil quenched and tempered, are to receive a suitable stress relief heat treatment before machining.

805 All heat treatments of castings are to be carried out in properly constructed furnaces which are efficiently maintained and have adequate means of temperature control of the furnace charge. Each casting is to be slowly and uniformly heated to the necessary temperature.

806 Unless otherwise agreed, test blocks are not to be removed from castings until all heat treatments have been completed. Test blocks are to receive the same heat treatment as the castings and are to be removed from castings and cut to provide test pieces by methods which do



not impair or modify the characteristics of the materials. Flame cutting is not permitted for the removal of test blocks from a casting or for cutting up test blocks to provide test pieces.

#### Provision of Test Material

**807** Unless otherwise approved, test material is to be provided by test blocks cast integral with or gated from each crankshaft. The test blocks are to be sufficient in number to allow of re-tests, if required. The dimensions of test blocks are to be such as to ensure that the material properties are similar to those of the average section of the crankshaft casting.

#### Dimensions of Test Pieces

**808** The diameter of a tensile test piece is to be as large as practicable. In general, it should not be less than 14 mm diameter.

A small flat is to be ground on each crankshaft casting and the Brinell hardness determined.

#### Number of Tests

**809** At least one tensile test piece is to be taken for each crankshaft.

#### Testing Machines

**810** Tensile tests are to be carried out by competent personnel in an approved machine of adequate capacity. The machine is to be maintained in an efficient and accurate condition and is to be checked and calibrated at suitable intervals agreed by the Society.

#### Mechanical Properties

**811** The results of the tensile and hardness tests are to comply with the approved specification for the material.

#### Additional Tests Before Rejection

**812** Where the results of a tensile test do not comply with the specification, two re-tests are permitted. If the results of both re-tests are satisfactory the casting is acceptable as regards the tensile test. If either of the re-tests fails the casting is unacceptable. For castings which were fully heat treated, re-heat treatment followed by re-testing may be permitted provided the size of the residue of the test block(s) is suitable, and the agreement of the Surveyor is obtained.

#### Batch Testing

**813** In the case of small shafts which are produced in quantity and are heat treated together, a system of batch

testing may be adopted with the agreement of the Surveyor. In these cases, however, not less than two test pieces are required per melt of which one is to represent the first shaft to be cast and the other the last shaft to be cast.

#### Inspection of Castings

**814** Where surplus material is to be removed from crankshaft castings before despatch, a machining method is to be employed. Flame cutting is not permissible.

Finished castings which have passed test are to be examined by the Surveyor before despatch. The castings are to be in a clean condition so that all surfaces may be examined including those of bores. Castings are to be free from cracks and other detrimental defects. Cast iron crankshafts are not to be repaired by welding and blemishes are not to be plugged with a filler.

#### Branding

**815** Every casting, after it has withstood satisfactorily the prescribed tests and inspection, is to be clearly marked by the Surveyor indicating that the casting has complied with the requirements of the Society.

In the event of any casting proving unsound during machining or at any subsequent stage of survey, it is to be rejected notwithstanding any previous certificate of satisfactory test and inspection.

#### Surface Treatment

**816** Where it is proposed to harden the surfaces of machined pins and/or journals of cast iron crankshafts, details of the process are to be submitted for approval. Before such a process is applied to a crankshaft it is to be demonstrated by procedure tests and to the satisfaction of the Surveyor, that the process is suitably controlled and does not impair the strength or soundness of the material.

### Section 9

#### COPPER ALLOY PROPELLERS AND PROPELLER BLADES

##### Scope

**901** Propeller and propeller blade castings in non-ferrous alloys are to be manufactured and tested in accordance with the requirements of this Section and, where applicable, with the general requirements given in Q 1 and Q 2.

Alternatively, castings complying with National or proprietary specifications may be accepted, provided that these specifications give reasonable equivalence to the requirements of this Section.



**Manufacture**

902 Castings exceeding 3 tonnes in finished weight are to be made at foundries approved by the Committee.

**Chemical Composition**

903 (a) The chemical composition of samples from each cast are to comply with the requirements given in Table Q 9.1. In addition to carrying out chemical analysis for the elements given in the Table, it is expected that manufacturers will ensure that other harmful residual elements are within acceptable limits.

The manufacturer is to maintain permanent records of all chemical analyses which are to be made available to the Surveyor so that he can satisfy himself that the chemical composition of each casting is within the specified limits.

(b) When a cast is wholly prepared from ingots for which an analysis is already available, and provided no significant alloy additions are made during melting, the ingot maker's certified analysis can be accepted subject to occasional checks as required by the Surveyor.

(c) Where it is proposed to use an alloy which is not included in Table Q 9.1, details of chemical composition, heat treatment and mechanical properties are to be submitted for approval.

**Heat Treatment**

904 At the option of the manufacturer, castings may be supplied in the "as cast" or heat treated condition.

**Test Material**

905 (a) Test samples for the preparation of tensile test pieces are to be provided from each cast used for the

manufacture of propeller or propeller blade castings. The test samples are to be of the keel block type, and are to be separately cast in sand moulds at the same time and from the same ladle as the castings which they represent.

(b) The method and procedures for the identification of the test samples and the castings they represent are to be agreed with the Surveyor. In general, the identification of the test samples at the time of casting should be in the form of a suitable metal tag inserted in the feeder head before solidification. The tag is to carry identification symbols which will identify the cast and the items represented by the test samples. The identification marks are to be transferred and maintained during the preparation of the test pieces. Where propeller castings are in regular production, and subject to agreement between the manufacturer and the Surveyor, the responsibility for test material identification may be assigned to a specific member of the manufacturer's personnel authorized by the Surveyor.

(c) One tensile test piece representative of each cast is to be prepared and tested by the manufacturer before the castings are despatched.

The dimensions of this test piece are to be in accordance with Q 201 (a) and the diameter is to be not less than 14 mm.

(d) Where the castings are supplied in a heat treated condition, the test samples are to be similarly heat treated prior to the preparation of the tensile test pieces.

**Mechanical Properties**

906 (a) The results of all tensile tests are to comply with the requirements given in Table Q 9.2.

TABLE Q 9.1

## CHEMICAL COMPOSITION OF PROPELLER AND PROPELLER BLADE CASTINGS

ALLOY DESIGNATION	CHEMICAL COMPOSITION OF LADLE SAMPLES, PER CENT							
	Cu	Sn	Zn	Pb	Ni	Fe	Al	Mn
A1. Manganese Bronze (high tensile brass)—low nickel	54 min.	0,2–1,5	Remainder	0,6 max.	2,5 max.	0,5–2,0	2,5 max.	5,0 max.
A2. Manganese Bronze (high tensile brass)—high nickel	52 min.	0,2–1,5	Remainder	0,6 max.	2,5 min.	0,5–2,5	2,5 max.	5,0 max.
B1. Aluminium Bronze—high manganese	Remainder	1,0 max.	7,0 max.	0,05 max.	1,0–3,0	2,0–5,0	6,0–10,0	8,0–20,0
B2. Aluminium Bronze—high nickel	Remainder	0,1 max.	1,0 max.	0,01 max.	3,0–6,0	2,0–6,0	6,0–11,0	3,0 max.



TABLE Q 9.2

MECHANICAL PROPERTIES OF PROPELLER AND PROPELLER  
BLADE CASTINGS

ALLOY DESIGNATION	TENSILE STRENGTH MINIMUM	ELONGATION (on $5.65\sqrt{S_0}$ ) PER CENT MINIMUM
	N/mm <sup>2</sup>	
A1. Manganese Bronze (high tensile brass)—low nickel	460	18
A2. Manganese Bronze (high tensile brass)—high nickel	460	18
B1. Aluminium Bronze—high manganese	630	14
B2. Aluminium Bronze—high nickel	630	14

**Re-tests**

(b) Where the specified minimum percentage elongation is not obtained, and the distance between the fracture and nearer gauge mark is less than one-third of the original gauge length, the test piece is to be discarded. A further test piece is to be prepared and the quality of the material is to be judged on the results obtained from this additional test.

(c) Except as provided by (b) above, where the results of a test fail to meet the requirements, two further test pieces from the same cast are to be tested in the same manner. If satisfactory results are obtained from one of these further test pieces, the casting or castings which they represent may be accepted. If both of these further tests fail to meet the requirements, the casting or castings which they represent are to be rejected.

**Inspection**

**907** (a) All castings are to be cleaned and the surfaces adequately prepared for visual examination. For propellers with a finished weight in excess of 15 tonnes an area on the pressure face of each blade adjacent to the toe of the fillet is to be polished for careful visual examination and then subjected to a suitable dye penetrant test. This area is to be about 250 mm wide and extending over an arc where the blade thickness is greater than two-thirds of the maximum thickness.

(b) All castings are to be free from harmful defects.

(c) The Surveyor is to examine each finished casting before final acceptance at the foundry.

(d) In addition to complying with the specified chemical composition, a sample from each tensile test piece representative of manganese bronze (low and high nickel) propeller castings is to be polished and etched for metallographic examination. The proportion of alpha phase determined from the average of at least five counts is to be not less than 25 per cent.

**Repair of Defects**

**908** Except for the rectification of minor imperfections in areas of low stress, the repair of castings by welding is subject to special consideration. Information on the position and extent of all defects together with full details of the proposed repair procedure are to be submitted to the Surveyor and his written consent obtained prior to commencing repairs.

**Identification**

**909** Castings are to be identified in accordance with Q 109.

**Documentation**

**910** For each casting, the manufacturer is to provide the Surveyor with a written statement giving the alloy designation and/or trade name, propeller or blade number, cast identification number, mechanical test results and, if applicable, details of heat treatment together with full particulars of the purchaser, order number, ship number (if known) and description.



# APPENDIX 1

## CONVERSION TABLES FOR USE WITH CHAPTERS P AND Q

TABLE P AND Q, A1.1

### CONVERSIONS FOR TENSILE STRENGTH VALUES AT AMBIENT TEMPERATURE

Values rounded to nearest multiple of: 1 kgf/mm<sup>2</sup>; 0.5 tonf/in<sup>2</sup>; 1 × 10<sup>3</sup> lbf/in<sup>2</sup>

N/mm <sup>2</sup> or MPa	kgf/mm <sup>2</sup>	tonf/in <sup>2</sup>	lbf/in <sup>2</sup> × 10 <sup>3</sup>	N/mm <sup>2</sup> or MPa	kgf/mm <sup>2</sup>	tonf/in <sup>2</sup>	lbf/in <sup>2</sup> × 10 <sup>3</sup>
200	20	13.0	29	700	71	45.5	102
210	21	13.5	30	710	72	46.0	103
220	22	14.0	32	720	73	46.5	104
230	23	15.0	33	730	74	47.5	106
240	24	15.5	35	740	75	48.0	107
250	25	16.0	36	750	76	48.5	109
260	27	17.0	38	760	77	49.0	110
270	28	17.5	39	770	79	50.0	112
280	29	18.0	41	780	80	50.5	113
290	30	19.0	42	790	81	51.0	115
300	31	19.5	44	800	82	52.0	116
310	32	20.0	45	810	83	52.5	117
320	33	20.5	46	820	84	53.0	119
330	34	21.5	48	830	85	53.5	120
340	35	22.0	49	840	86	54.5	122
350	36	22.5	51	850	87	55.0	123
360	37	23.5	52	860	88	55.5	125
370	38	24.0	54	870	89	56.5	126
380	39	24.5	55	880	90	57.0	128
390	40	25.5	57	890	91	57.5	129
400	41	26.0	58	900	92	58.5	131
410	42	26.5	59	910	93	59.0	132
420	43	27.0	61	920	94	59.5	133
430	44	28.0	62	930	95	60.0	135
440	45	28.5	64	940	96	61.0	136
450	46	29.0	65	950	97	61.5	138
460	47	30.0	67	960	98	62.0	139
470	48	30.5	68	970	99	63.0	141
480	49	31.0	70	980	100	63.5	142
490	50	31.5	71	990	101	64.0	144
500	51	32.5	73	1000	102	64.5	145
510	52	33.0	74	1010	103	65.5	146
520	53	33.5	75	1020	104	66.0	148
530	54	34.5	77	1030	105	66.5	149
540	55	35.0	78	1040	106	67.5	151
550	56	35.5	80	1050	107	68.0	152
560	57	36.5	81	1060	108	68.5	154
570	58	37.0	83	1070	109	69.5	155
580	59	37.5	84	1080	110	70.0	157
590	60	38.0	86	1090	111	70.5	158
600	61	39.0	87	1100	112	71.0	160
610	62	39.5	88	1110	113	72.0	161
620	63	40.0	90	1120	114	72.5	162
630	64	41.0	91	1130	115	73.0	164
640	65	41.5	93	1140	116	74.0	165
650	66	42.0	94	1150	117	74.5	167
660	67	42.5	96	1160	118	75.0	168
670	68	43.5	97	1170	119	76.0	170
680	69	44.0	99	1180	120	76.5	171
690	70	44.5	100	1190	121	77.0	173
				1200	122	77.5	174

TABLE P AND Q, A1.2

## CONVERSIONS FOR YIELD STRESS VALUES AT AMBIENT TEMPERATURE

Values rounded to nearest multiple of: 0,5 kgf/mm<sup>2</sup>; 0.2 tonf/in<sup>2</sup>; 0.5×10<sup>3</sup> lbf/in<sup>2</sup>

N/mm <sup>2</sup> or MPa	kgf/mm <sup>2</sup>	tonf/in <sup>2</sup>	lbf/in <sup>2</sup> × 10 <sup>3</sup>	N/mm <sup>2</sup> or MPa	kgf/mm <sup>2</sup>	tonf/in <sup>2</sup>	lbf/in <sup>2</sup> × 10 <sup>3</sup>	N/mm <sup>2</sup> or MPa	kgf/mm <sup>2</sup>	tonf/in <sup>2</sup>	lbf/in <sup>2</sup> × 10 <sup>3</sup>
50	5,0	3.2	7.5	350	35,5	22.6	51.0	650	66,5	42.0	94.5
55	5,5	3.6	8.0	355	36,0	23.0	51.5	655	67,0	42.4	95.0
60	6,0	3.8	8.5	360	36,5	23.4	52.0	660	67,5	42.8	95.5
65	6,5	4.2	9.5	365	37,0	23.6	53.0	665	68,0	43.0	96.5
70	7,0	4.6	10.0	370	37,5	24.0	53.5	670	68,5	43.4	97.0
75	7,5	4.8	11.0	375	38,0	24.2	54.5	675	69,0	43.8	98.0
80	8,0	5.2	11.5	380	38,5	24.6	55.0	680	69,5	44.0	98.5
85	8,5	5.6	12.5	385	39,5	25.0	56.0	685	70,0	44.4	99.5
90	9,0	5.8	13.0	390	40,0	25.2	56.5	690	70,5	44.6	100.0
95	9,5	6.2	14.0	395	40,5	25.6	57.5	695	71,0	45.0	101.0
100	10,0	6.4	14.5	400	41,0	25.8	58.0	700	71,5	45.4	101.5
105	10,5	6.8	15.0	405	41,5	26.2	58.5	705	72,0	45.6	102.5
110	11,0	7.2	16.0	410	42,0	26.6	59.5	710	72,5	46.0	103.0
115	11,5	7.4	16.5	415	42,5	26.8	60.0	715	73,0	46.2	103.5
120	12,0	7.8	17.5	420	43,0	27.2	61.0	720	73,5	46.6	104.5
125	12,5	8.0	18.0	425	43,5	27.6	61.5	725	74,0	47.0	105.0
130	13,5	8.4	19.0	430	44,0	27.8	62.5	730	74,5	47.2	106.0
135	14,0	8.8	19.5	435	44,5	28.2	63.0	735	75,0	47.6	106.5
140	14,5	9.0	20.5	440	45,0	28.4	64.0	740	75,5	48.0	107.5
145	15,0	9.4	21.0	445	45,5	28.8	64.5	745	76,0	48.2	108.0
150	15,5	9.8	22.0	450	46,0	29.2	65.5	750	76,5	48.6	109.0
155	16,0	10.0	22.5	455	46,5	29.4	66.0	755	77,0	48.8	109.5
160	16,5	10.4	23.0	460	47,0	29.6	66.5	760	77,5	49.2	110.0
165	17,0	10.6	24.0	465	47,5	30.2	67.5	765	78,0	49.6	111.0
170	17,5	11.0	24.5	470	48,0	30.4	68.0	770	78,5	49.8	111.5
175	18,0	11.4	25.5	475	48,5	30.8	69.0	775	79,0	50.2	112.5
180	18,5	11.6	26.0	480	49,0	31.0	69.5	780	79,5	50.6	113.0
185	19,0	12.0	27.0	485	49,5	31.4	70.5	785	80,0	50.8	114.0
190	19,5	12.4	27.5	490	50,0	31.8	71.0	790	80,5	51.2	114.5
195	20,0	12.6	28.5	495	50,5	32.0	72.0	795	81,0	51.4	115.5
200	20,5	13.0	29.0	500	51,0	32.4	72.5	800	81,5	51.8	116.0
205	21,0	13.2	29.5	505	51,5	32.6	73.0	805	82,0	52.2	117.0
210	21,5	13.6	30.5	510	52,0	33.0	74.0	810	82,5	52.4	117.5
215	22,0	14.0	31.0	515	52,5	33.4	74.5	815	83,0	52.8	118.0
220	22,5	14.2	32.0	520	53,0	33.6	75.5	820	83,5	53.0	119.0
225	23,0	14.6	32.5	525	53,5	34.0	76.0	825	84,0	53.4	119.5
230	23,5	14.8	33.5	530	54,0	34.4	77.0	830	84,5	53.8	120.5
235	24,0	15.2	34.0	535	54,5	34.6	77.5	835	85,0	54.0	121.0
240	24,5	15.6	35.0	540	55,0	35.0	78.5	840	85,5	54.4	122.0
245	25,0	15.8	35.5	545	55,5	35.2	79.0	845	86,0	54.8	122.5
250	25,5	16.2	36.5	550	56,0	35.6	80.0	850	86,5	55.0	123.5
255	26,0	16.6	37.0	555	56,5	36.0	80.5	855	87,0	55.4	124.0
260	26,5	16.8	37.5	560	57,0	36.2	81.0	860	87,5	55.6	124.5
265	27,0	17.2	38.5	565	57,5	36.6	82.0	865	88,0	56.0	125.5
270	27,5	17.4	39.0	570	58,0	37.0	82.5	870	88,5	56.4	126.0
275	28,0	17.8	40.0	575	58,5	37.2	83.5	875	89,0	56.6	127.0
280	28,5	18.2	40.5	580	59,0	37.6	84.0	880	89,5	57.0	127.5
285	29,0	18.4	41.5	585	59,5	37.8	85.0	885	90,0	57.4	128.5
290	29,5	18.8	42.0	590	60,0	38.2	85.5	890	91,0	57.6	129.0
295	30,0	19.2	43.0	595	60,5	38.6	86.5	895	91,5	58.0	130.0
300	30,5	19.4	43.5	600	61,0	38.8	87.0	900	92,0	58.2	130.5
305	31,0	19.8	44.0	605	61,5	39.2	87.5	905	92,5	58.6	131.5
310	31,5	20.0	45.0	610	62,0	39.4	88.5	910	93,0	59.0	132.0
315	32,0	20.4	45.5	615	62,5	39.8	89.0	915	93,5	59.2	132.5
320	32,5	20.8	46.5	620	63,0	40.2	90.0	920	94,0	59.6	133.5
325	33,0	21.0	47.0	625	63,5	40.4	90.5	925	94,5	59.8	134.0
330	33,5	21.4	48.0	630	64,0	40.8	91.5	930	95,0	60.2	135.0
335	34,0	21.6	48.5	635	65,0	41.2	92.0	935	95,5	60.6	135.5
340	34,5	22.0	49.5	640	65,5	41.4	93.0	940	96,0	60.8	136.5
345	35,0	22.4	50.0	645	66,0	41.8	93.5	945	96,5	61.2	137.0
								950	97,0	61.6	138.0



TABLE P AND Q, A1.3 (see continuation)

CONVERSIONS FOR LOWER YIELD OR 0.2% PROOF STRESS VALUES AND  
STRESS TO RUPTURE VALUES AT ELEVATED TEMPERATURES

Values rounded to nearest multiple of: 0.1 kgf/mm<sup>2</sup>; 0.05 tonf/in<sup>2</sup>; 0.1 × 10<sup>3</sup> lbf/in<sup>2</sup>

N/mm <sup>2</sup> or MPa	kgf/mm <sup>2</sup>	tonf/in <sup>2</sup>	lbf/in <sup>2</sup> × 10 <sup>3</sup>	N/mm <sup>2</sup> or MPa	kgf/mm <sup>2</sup>	tonf/in <sup>2</sup>	lbf/in <sup>2</sup> × 10 <sup>3</sup>	N/mm <sup>2</sup> or MPa	kgf/mm <sup>2</sup>	tonf/in <sup>2</sup>	lbf/in <sup>2</sup> × 10 <sup>3</sup>
10	1.0	0.65	1.5	70	7.1	4.55	10.2	130	13.3	8.40	18.9
11	1.1	0.70	1.6	71	7.2	4.60	10.3	131	13.4	8.50	19.0
12	1.2	0.80	1.7	72	7.3	4.65	10.4	132	13.5	8.55	19.1
13	1.3	0.85	1.9	73	7.4	4.75	10.6	133	13.6	8.60	19.3
14	1.4	0.90	2.0	74	7.5	4.80	10.7	134	13.7	8.70	19.4
15	1.5	0.95	2.2	75	7.6	4.85	10.9	135	13.8	8.75	19.6
16	1.6	1.05	2.3	76	7.7	4.90	11.0	136	13.9	8.80	19.7
17	1.7	1.10	2.5	77	7.9	5.00	11.2	137	14.0	8.85	19.9
18	1.8	1.15	2.6	78	8.0	5.05	11.3	138	14.1	8.95	20.0
19	1.9	1.25	2.8	79	8.1	5.10	11.5	139	14.2	9.00	20.2
20	2.0	1.30	2.9	80	8.2	5.20	11.6	140	14.3	9.05	20.3
21	2.1	1.35	3.0	81	8.3	5.25	11.7	141	14.4	9.15	20.5
22	2.2	1.40	3.2	82	8.4	5.30	11.9	142	14.5	9.20	20.6
23	2.3	1.50	3.3	83	8.5	5.35	12.0	143	14.6	9.25	20.7
24	2.4	1.55	3.5	84	8.6	5.45	12.2	144	14.7	9.30	20.9
25	2.5	1.60	3.6	85	8.7	5.50	12.3	145	14.8	9.40	21.0
26	2.7	1.70	3.8	86	8.8	5.55	12.5	146	14.9	9.45	21.2
27	2.8	1.75	3.9	87	8.9	5.65	12.6	147	15.0	9.50	21.3
28	2.9	1.80	4.1	88	9.0	5.70	12.8	148	15.1	9.60	21.5
29	3.0	1.90	4.2	89	9.1	5.75	12.9	149	15.2	9.65	21.6
30	3.1	1.95	4.4	90	9.2	5.85	13.1	150	15.3	9.70	21.8
31	3.2	2.00	4.5	91	9.3	5.90	13.2	151	15.4	9.80	21.9
32	3.3	2.05	4.6	92	9.4	5.95	13.3	152	15.5	9.85	22.0
33	3.4	2.15	4.8	93	9.5	6.00	13.5	153	15.6	9.90	22.2
34	3.5	2.20	4.9	94	9.6	6.10	13.6	154	15.7	9.95	22.3
35	3.6	2.25	5.1	95	9.7	6.15	13.8	155	15.8	10.00	22.5
36	3.7	2.35	5.2	96	9.8	6.20	13.9	156	15.9	10.10	22.6
37	3.8	2.40	5.4	97	9.9	6.30	14.1	157	16.0	10.15	22.8
38	3.9	2.45	5.5	98	10.0	6.35	14.2	158	16.1	10.25	22.9
39	4.0	2.55	5.7	99	10.1	6.40	14.4	159	16.2	10.30	23.1
40	4.1	2.60	5.8	100	10.2	6.45	14.5	160	16.3	10.35	23.2
41	4.2	2.65	5.9	101	10.3	6.55	14.6	161	16.4	10.40	23.4
42	4.3	2.70	6.1	102	10.4	6.60	14.8	162	16.5	10.50	23.5
43	4.4	2.80	6.2	103	10.5	6.65	14.9	163	16.6	10.55	23.6
44	4.5	2.85	6.4	104	10.6	6.75	15.1	164	16.7	10.60	23.8
45	4.6	2.90	6.5	105	10.7	6.80	15.2	165	16.8	10.70	23.9
46	4.7	3.00	6.7	106	10.8	6.85	15.4	166	16.9	10.75	24.1
47	4.8	3.05	6.8	107	10.9	6.95	15.5	167	17.0	10.80	24.2
48	4.9	3.10	7.0	108	11.0	7.00	15.7	168	17.1	10.90	24.4
49	5.0	3.15	7.1	109	11.1	7.05	15.8	169	17.2	10.95	24.5
50	5.1	3.25	7.3	110	11.2	7.10	16.0	170	17.3	11.00	24.7
51	5.2	3.30	7.4	111	11.3	7.20	16.1	171	17.4	11.05	24.8
52	5.3	3.35	7.5	112	11.4	7.25	16.2	172	17.5	11.15	24.9
53	5.4	3.45	7.7	113	11.5	7.30	16.4	173	17.6	11.20	25.1
54	5.5	3.50	7.8	114	11.6	7.40	16.5	174	17.7	11.25	25.2
55	5.6	3.55	8.0	115	11.7	7.45	16.7	175	17.8	11.35	25.4
56	5.7	3.65	8.1	116	11.8	7.50	16.8	176	17.9	11.40	25.5
57	5.8	3.70	8.3	117	11.9	7.60	17.0	177	18.0	11.45	25.7
58	5.9	3.75	8.4	118	12.0	7.65	17.1	178	18.2	11.55	25.8
59	6.0	3.80	8.6	119	12.1	7.70	17.3	179	18.3	11.60	26.0
60	6.1	3.90	8.7	120	12.2	7.75	17.4	180	18.4	11.65	26.1
61	6.2	3.95	8.8	121	12.3	7.85	17.5	181	18.5	11.70	26.3
62	6.3	4.00	9.0	122	12.4	7.90	17.7	182	18.6	11.80	26.4
63	6.4	4.10	9.1	123	12.5	7.95	17.8	183	18.7	11.85	26.5
64	6.5	4.15	9.3	124	12.6	8.00	18.0	184	18.8	11.90	26.7
65	6.6	4.20	9.4	125	12.7	8.10	18.1	185	18.9	12.00	26.8
66	6.7	4.25	9.6	126	12.8	8.15	18.3	186	19.0	12.05	27.0
67	6.8	4.35	9.7	127	13.0	8.20	18.4	187	19.1	12.10	27.1
68	6.9	4.40	9.9	128	13.1	8.30	18.6	188	19.2	12.15	27.3
69	7.0	4.45	10.0	129	13.2	8.35	18.7	189	19.3	12.25	27.4



TABLE P AND Q, A1.3 (Conclusion)

**CONVERSIONS FOR LOWER YIELD OR 0.2% PROOF STRESS VALUES AND  
STRESS TO RUPTURE VALUES AT ELEVATED TEMPERATURES**

Values rounded to nearest multiple of: 0.1 kgf/mm<sup>2</sup>; 0.05 tonf/in<sup>2</sup>; 0.1 × 10<sup>3</sup> lbf/in<sup>2</sup>

N/mm <sup>2</sup> or MPa	kgf/mm <sup>2</sup>	tonf/in <sup>2</sup>	lbf/in <sup>2</sup> × 10 <sup>3</sup>	N/mm <sup>2</sup> or MPa	kgf/mm <sup>2</sup>	tonf/in <sup>2</sup>	lbf/in <sup>2</sup> × 10 <sup>3</sup>	N/mm <sup>2</sup> or MPa	kgf/mm <sup>2</sup>	tonf/in <sup>2</sup>	lbf/in <sup>2</sup> × 10 <sup>3</sup>
190	19.4	12.30	27.6	250	25.5	16.20	36.3	310	31.6	20.05	45.0
191	19.5	12.35	27.7	251	25.6	16.25	36.4	311	31.7	20.15	45.1
192	19.6	12.45	27.8	252	25.7	16.30	36.5	312	31.8	20.20	45.3
193	19.7	12.50	28.0	253	25.8	16.40	36.7	313	31.9	20.25	45.4
194	19.8	12.55	28.1	254	25.9	16.45	36.8	314	32.0	20.35	45.5
195	19.9	12.65	28.3	255	26.0	16.50	37.0	315	32.1	20.40	45.7
196	20.0	12.70	28.4	256	26.1	16.60	37.1	316	32.2	20.45	45.8
197	20.1	12.75	28.6	257	26.2	16.65	37.3	317	32.3	20.55	46.0
198	20.2	12.80	28.7	258	26.3	16.70	37.4	318	32.4	20.60	46.1
199	20.3	12.90	28.9	259	26.4	16.75	37.6	319	32.5	20.65	46.3
200	20.4	12.95	29.0	260	26.5	16.85	37.7	320	32.6	20.70	46.4
201	20.5	13.00	29.2	261	26.6	16.90	37.9	321	32.7	20.80	46.6
202	20.6	13.10	29.3	262	26.7	16.95	38.0	322	32.8	20.85	46.7
203	20.7	13.15	29.4	263	26.8	17.05	38.1	323	32.9	20.90	46.8
204	20.8	13.20	29.6	264	26.9	17.10	38.3	324	33.0	21.00	47.0
205	20.9	13.25	29.7	265	27.0	17.15	38.4	325	33.1	21.05	47.1
206	21.0	13.35	29.9	266	27.1	17.20	38.6	326	33.2	21.10	47.3
207	21.1	13.40	30.0	267	27.2	17.30	38.7	327	33.3	21.15	47.4
208	21.2	13.45	30.2	268	27.3	17.35	38.9	328	33.4	21.25	47.6
209	21.3	13.55	30.3	269	27.4	17.40	39.0	329	33.5	21.30	47.7
210	21.4	13.60	30.5	270	27.5	17.50	39.2	330	33.7	21.35	47.9
211	21.5	13.65	30.6	271	27.6	17.55	39.3	331	33.8	21.45	48.0
212	21.6	13.75	30.7	272	27.7	17.60	39.5	332	33.9	21.50	48.2
213	21.7	13.80	30.9	273	27.8	17.70	39.6	333	34.0	21.55	48.3
214	21.8	13.85	31.0	274	27.9	17.75	39.7	334	34.1	21.65	48.4
215	21.9	13.90	31.2	275	28.0	17.80	39.9	335	34.2	21.70	48.6
216	22.0	14.00	31.3	276	28.1	17.85	40.0	336	34.3	21.75	48.7
217	22.1	14.05	31.5	277	28.2	17.95	40.2	337	34.4	21.80	48.9
218	22.2	14.10	31.6	278	28.3	18.00	40.3	338	34.5	21.90	49.0
219	22.3	14.20	31.8	279	28.5	18.05	40.5	339	34.6	21.95	49.2
220	22.4	14.25	31.9	280	28.6	18.15	40.6	340	34.7	22.00	49.3
221	22.5	14.30	32.1	281	28.7	18.20	40.8	341	34.8	22.10	49.5
222	22.6	14.35	32.2	282	28.8	18.25	40.9	342	34.9	22.15	49.6
223	22.7	14.45	32.3	283	28.9	18.30	41.0	343	35.0	22.20	49.7
224	22.8	14.50	32.5	284	29.0	18.40	41.2	344	35.1	22.25	49.9
225	22.9	14.55	32.6	285	29.1	18.45	41.3	345	35.2	22.35	50.0
226	23.0	14.65	32.8	286	29.2	18.50	41.5	346	35.3	22.40	50.2
227	23.1	14.70	32.9	287	29.3	18.60	41.6	347	35.4	22.45	50.3
228	23.2	14.75	33.1	288	29.4	18.65	41.8	348	35.5	22.55	50.5
229	23.4	14.85	33.2	289	29.5	18.70	41.9	349	35.6	22.60	50.6
230	23.5	14.90	33.4	290	29.6	18.80	42.1	350	35.7	22.65	50.8
231	23.6	14.95	33.5	291	29.7	18.85	42.2	351	35.8	22.75	50.9
332	23.7	15.00	33.6	292	29.8	18.90	42.4	352	35.9	22.80	51.1
233	23.8	15.10	33.8	293	29.9	18.95	42.5	353	36.0	22.85	51.2
234	23.9	15.15	33.9	294	30.0	19.05	42.6	354	36.1	22.90	51.3
235	24.0	15.20	34.1	295	30.1	19.10	42.8	355	36.2	23.00	51.5
236	24.1	15.30	34.2	296	30.2	19.15	42.9	356	36.3	23.05	51.6
237	24.2	15.35	34.4	297	30.3	19.25	43.1	357	36.4	23.10	51.8
238	24.3	15.40	34.5	298	30.4	19.30	43.2	358	36.5	23.20	51.9
239	24.4	15.50	34.7	299	30.5	19.35	43.4	359	36.6	23.25	52.1
240	24.5	15.55	34.8	300	30.6	19.40	43.5	360	36.7	23.30	52.2
241	24.6	15.60	35.0	301	30.7	19.50	43.7	361	36.8	23.35	52.4
242	24.7	15.65	35.1	302	30.8	19.55	43.8	362	36.9	23.45	52.5
243	24.8	15.75	35.2	303	30.9	19.60	43.9	363	37.0	23.50	52.6
244	24.9	15.80	35.4	304	31.0	19.70	44.1	364	37.1	23.55	52.8
245	25.0	15.85	35.5	305	31.1	19.75	44.2	365	37.2	23.65	52.9
246	25.1	15.95	35.7	306	31.2	19.80	44.4	366	37.3	23.70	53.1
247	25.2	16.00	35.8	307	31.3	19.90	44.5	367	37.4	23.75	53.2
248	25.3	16.05	36.0	308	31.4	19.95	44.7	368	37.5	23.85	53.4
249	25.4	16.10	36.1	309	31.5	20.00	44.8	369	37.6	23.90	53.5



CONVERSION TABLES FOR USE WITH CHAPTERS P AND Q

TABLE P AND Q, A1.4

CONVERSIONS FOR IMPACT ENERGY VALUES

Values rounded to nearest multiple of: 0,1 kgf m; 1 ft lbf

J	kgf m	ft lbf	J	kgf m	ft lbf
10	1,0	7	55	5,6	41
11	1,1	8	56	5,7	41
12	1,2	9	57	5,8	42
13	1,3	10	58	5,9	43
14	1,4	10	59	6,0	44
15	1,5	11	60	6,1	44
16	1,6	12	61	6,2	45
17	1,7	13	62	6,3	46
18	1,8	13	63	6,4	47
19	1,9	14	64	6,5	47
20	2,0	15	65	6,6	48
21	2,1	16	66	6,7	49
22	2,2	16	67	6,8	49
23	2,3	17	68	6,9	50
24	2,4	18	69	7,0	51
25	2,5	18	70	7,1	52
26	2,7	19	71	7,2	52
27	2,8	20	72	7,3	53
28	2,9	21	73	7,4	54
29	3,0	21	74	7,5	55
30	3,1	22	75	7,6	55
31	3,2	23	76	7,7	56
32	3,3	24	77	7,9	57
33	3,4	24	78	8,0	58
34	3,5	25	79	8,1	58
35	3,6	26	80	8,2	59
36	3,7	27	81	8,3	60
37	3,8	27	82	8,4	61
38	3,9	28	83	8,5	61
39	4,0	29	84	8,6	62
40	4,1	30	85	8,7	63
41	4,2	30	86	8,8	63
42	4,3	31	87	8,9	64
43	4,4	32	88	9,0	65
44	4,5	33	89	9,1	66
45	4,6	33	90	9,2	66
46	4,7	34	91	9,3	67
47	4,8	35	92	9,4	68
48	4,9	35	93	9,5	69
49	5,0	36	94	9,6	69
50	5,1	37	95	9,7	70
51	5,2	38	96	9,8	71
52	5,3	38	97	9,9	72
53	5,4	39	98	10,0	72
54	5,5	40	99	10,1	73
			100	10,2	74

TABLE P AND Q, A1.5

## CONVERSIONS FOR PROOF TESTS FOR ANCHORS—METRIC UNITS

For anchors having weights shown in the Table, the equivalent proof test loads in kN are given in Table P 7.1

WEIGHT OF ANCHOR (see P 705)	PROOF TEST LOAD	WEIGHT OF ANCHOR (see P 705)	PROOF TEST LOAD	WEIGHT OF ANCHOR (see P 705)	PROOF TEST LOAD	WEIGHT OF ANCHOR (see P 705)	PROOF TEST LOAD	WEIGHT OF ANCHOR (see P 705)	PROOF TEST LOAD	WEIGHT OF ANCHOR (see P 705)	PROOF TEST LOAD
kg	tonne-f	kg	tonne-f	kg	tonne-f	kg	tonne-f	kg	tonne-f	kg	tonne-f
50	2,37	550	12,70	2200	38,30	4800	65,80	7800	87,80	17 500	142,00
55	2,57	600	13,50	2300	39,60	4900	66,60	8000	89,40	18 000	144,00
60	2,76	650	14,30	2400	40,90	5000	67,40	8200	91,00	18 500	147,00
65	2,95	700	15,20	2500	42,20	5100	68,20	8400	92,60	19 000	150,00
70	3,13	750	16,10	2600	43,50	5200	69,00	8600	94,00	19 500	152,00
75	3,30	800	16,90	2700	44,70	5300	69,80	8800	95,40	20 000	155,00
80	3,46	850	17,80	2800	45,90	5400	70,50	9000	96,80	21 000	160,00
90	3,70	900	18,60	2900	47,10	5500	71,30	9200	98,00	22 000	165,00
100	3,99	950	19,50	3000	48,30	5600	72,00	9400	99,40	23 000	170,00
120	4,52	1000	20,30	3100	49,40	5700	72,70	9600	100,60	24 000	175,00
140	5,00	1050	21,20	3200	50,50	5800	73,50	9800	101,80	25 000	180,00
160	5,43	1100	22,00	3300	51,60	5900	74,20	10 000	103,00	26 000	184,00
180	5,85	1150	22,80	3400	52,70	6000	74,90	10 500	105,60	27 000	189,00
200	6,25	1200	23,60	3500	53,80	6100	75,50	11 000	109,00	28 000	194,00
225	6,71	1250	24,40	3600	54,80	6200	76,20	11 500	111,00	29 000	198,00
250	7,18	1300	25,20	3700	55,80	6300	76,90	12 000	113,00	30 000	203,00
275	7,64	1350	26,00	3800	56,80	6400	77,50	12 500	115,00	31 000	207,00
300	8,11	1400	26,70	3900	57,80	6500	78,20	13 000	118,00	32 000	211,00
325	8,58	1450	27,50	4000	58,80	6600	78,80	13 500	120,00	34 000	220,00
350	9,05	1500	28,30	4100	59,80	6700	79,40	14 000	123,00	36 000	229,00
375	9,52	1600	29,80	4200	60,70	6800	80,20	14 500	125,00	38 000	238,00
400	9,98	1700	31,30	4300	61,60	6900	81,00	15 000	128,00	40 000	246,00
425	10,50	1800	32,70	4400	62,50	7000	82,00	15 500	130,00	42 000	254,00
450	10,90	1900	34,20	4500	63,40	7200	83,40	16 000	133,00	44 000	262,00
475	11,40	2000	35,60	4600	64,30	7400	84,80	16 500	136,00	46 000	270,00
500	11,80	2100	36,90	4700	65,10	7600	86,20	17 000	139,00	48 000	278,00

## NOTES

- Proof loads for intermediate weights are to be determined by linear interpolation.
- Where anchors exceeding the Table value of weights are to be tested, the proof loads are to be taken as:—
 

for ordinary anchors	$0,210 (\text{anchor weight in kg})^{\frac{2}{3}} \text{ tonne-f}$
for high holding power anchors	$0,250 (\text{anchor weight in kg})^{\frac{2}{3}} \text{ tonne-f}$



CONVERSION TABLES FOR USE WITH CHAPTERS P AND Q

TABLE P AND Q, A1.6

CONVERSIONS FOR PROOF TESTS FOR ANCHORS—BRITISH UNITS

Conversion factors 1 cwt = 50,80 kg

1 tonf = 1,016 tonne-f = 9,96 kN

WEIGHT OF ANCHOR (see P 705)	PROOF TEST LOAD	WEIGHT OF ANCHOR (see P 705)	PROOF TEST LOAD	WEIGHT OF ANCHOR (see P 705)	PROOF TEST LOAD	WEIGHT OF ANCHOR (see P 705)	PROOF TEST LOAD	WEIGHT OF ANCHOR (see P 705)	PROOF TEST LOAD	WEIGHT OF ANCHOR (see P 705)	PROOF TEST LOAD
cwt	tonf	cwt	tonf	cwt	tonf	cwt	tonf	cwt	tonf	cwt	tonf
1	2.37	20	20.28	62	49.2	114	72.3	166	91.3	350	141.0
1 $\frac{1}{4}$	2.85	21	21.12	64	50.2	116	73.0	168	92.0	360	143.5
1 $\frac{1}{2}$	3.27	22	21.92	66	51.3	118	73.7	170	92.7	370	146.5
1 $\frac{3}{4}$	3.65	23	22.74	68	52.4	120	74.3	172	93.5	380	149.0
2	3.98	24	23.48	70	53.4	122	75.0	174	94.2	390	151.5
2 $\frac{1}{2}$	4.63	25	24.33	72	54.5	124	75.7	176	94.8	400	154.0
3	5.18	26	25.12	74	55.5	126	76.3	178	95.5	420	159.0
3 $\frac{1}{2}$	5.70	27	25.87	76	56.5	128	77.0	180	96.1	440	164.0
4	6.20	28	26.52	78	57.5	130	77.6	185	97.8	460	169.0
4 $\frac{1}{2}$	6.68	29	27.46	80	58.5	132	78.2	190	99.3	480	174.0
5	7.14	30	28.25	82	59.4	134	79.0	195	101.0	500	178.5
5 $\frac{1}{2}$	7.61	32	29.75	84	60.3	136	79.8	200	102.4	520	183.0
6	8.07	34	31.13	86	61.2	138	80.8	210	105.0	540	188.0
7	9.03	36	32.53	88	62.1	140	81.6	220	108.0	560	192.5
8	9.95	38	34.10	90	63.0	142	82.2	230	110.0	580	197.0
9	10.85	40	35.45	92	63.9	144	82.9	240	112.0	600	201.5
10	11.76	42	36.79	94	64.6	146	83.6	250	114.5	620	205.5
11	12.65	44	38.11	96	65.4	148	84.3	260	117.0	640	210.0
12	13.44	46	39.27	98	66.2	150	85.0	270	119.5	680	219.0
13	14.25	48	40.75	100	67.0	152	85.8	280	122.0	720	228.0
14	15.16	50	42.1	102	67.8	154	86.6	290	124.5	760	236.5
15	16.04	52	43.3	104	68.6	156	87.4	300	127.0	800	244.5
16	16.83	54	44.5	106	69.3	158	88.2	310	129.5	840	252.5
17	17.72	56	45.7	108	70.1	160	89.0	320	132.5	880	260.5
18	18.55	58	46.9	110	70.8	162	89.8	330	135.5	920	268.5
19	19.44	60	48.1	112	71.5	164	90.6	340	138.5	960	276.5

NOTES

1. Proof loads for intermediate weights are to be determined by linear interpolation.
2. Where anchors exceeding the Table value of weights are to be tested, the proof loads are to be taken as:
 

for ordinary anchors	$2.833 (\text{anchor weight in cwt})^{\frac{2}{3}} \text{ tonf}$
for high holding power anchors	$3.373 (\text{anchor weight in cwt})^{\frac{2}{3}} \text{ tonf}$

TABLE P AND Q, A1.7

## CONVERSIONS FOR STUD LINK CHAIN CABLE—METRIC UNITS

For chains having diameters shown in the Table, the equivalent proof loads and breaking loads in kN are given in Table P 8.3.

CHAIN DIAMETER	GRADE					
	U1		U 2		U 3	
	Proof Load	Breaking Load	Proof Load	Breaking Load	Proof Load	Breaking Load
mm	tonne-f	tonne-f	tonne-f	tonne-f	tonne-f	tonne-f
12,5	4,7	6,7	6,7	9,4	9,4	13,5
14	5,9	8,4	8,4	11,8	11,8	16,8
16	7,7	10,9	10,9	15,3	15,3	22,0
17,5	9,1	13,0	13,0	18,3	18,3	26,1
19	10,7	15,3	15,3	21,5	21,5	30,7
20,5	12,5	17,8	17,8	24,9	24,9	35,6
22	14,3	20,4	20,4	28,6	28,6	40,9
24	17,0	24,2	24,2	33,9	33,9	48,5
26	19,8	28,3	28,3	39,7	39,7	56,7
28	22,9	32,7	32,7	45,8	45,8	65,5
30	26,2	37,5	37,5	52,4	52,4	74,9
32	29,7	42,5	42,5	59,4	59,4	84,9
34	33,4	47,7	47,7	66,8	66,8	95,5
36	37,3	53,3	53,3	74,6	74,6	107,0
38	41,4	59,2	59,2	82,8	82,8	118,0
40	45,7	65,3	65,3	91,4	91,4	131,0
42	50,2	71,7	71,7	100,0	100,0	143,0
44	54,9	78,4	78,4	110,0	110,0	157,0
46	59,7	85,3	85,3	119,0	119,0	171,0
48	64,8	92,6	92,6	130,0	130,0	185,0
50	70,0	100,0	100,0	140,0	140,0	200,0
52	75,4	108,0	108,0	151,0	151,0	215,0
54	81,0	116,0	116,0	162,0	162,0	231,0
56	86,8	124,0	124,0	174,0	174,0	248,0
58	92,7	132,0	132,0	185,0	185,0	265,0
60	98,8	141,0	141,0	198,0	198,0	282,0
62	105,0	150,0	150,0	210,0	210,0	300,0
64	112,0	159,0	159,0	223,0	223,0	319,0
66	118,0	169,0	169,0	236,0	236,0	337,0
68	125,0	178,0	178,0	250,0	250,0	357,0
70	132,0	188,0	188,0	263,0	263,0	376,0
73	142,0	203,0	203,0	285,0	285,0	407,0
76	153,0	219,0	219,0	307,0	307,0	438,0
78	161,0	230,0	230,0	322,0	322,0	459,0
81	172,0	246,0	246,0	345,0	345,0	492,0
84	184,0	263,0	263,0	368,0	368,0	526,0
87	196,0	280,0	280,0	393,0	393,0	561,0
90	209,0	298,0	298,0	417,0	417,0	596,0
92	217,0	310,0	310,0	434,0	434,0	620,0
95	230,0	329,0	329,0	460,0	460,0	657,0
97	239,0	341,0	341,0	477,0	477,0	682,0
100	252,0	360,0	360,0	504,0	504,0	720,0
102	261,0	373,0	373,0	522,0	522,0	746,0
105	275,0	393,0	393,0	550,0	550,0	785,0
107	284,0	406,0	406,0	568,0	568,0	812,0
111	303,0	433,0	433,0	606,0	606,0	865,0
114	317,0	453,0	453,0	635,0	635,0	907,0
117	332,0	474,0	474,0	664,0	664,0	948,0
120	347,0	495,0	495,0	694,0	694,0	991,0
122	357,0	510,0	510,0	714,0	714,0	1019,0
124	367,0	524,0	524,0	734,0	734,0	1048,0
127	382,0	546,0	546,0	764,0	764,0	1092,0
130	398,0	568,0	568,0	795,0	795,0	1136,0
132	408,0	583,0	583,0	816,0	816,0	1165,0
137	434,0	620,0	620,0	868,0	868,0	1240,0
142	461,0	658,0	658,0	921,0	921,0	1316,0
147	488,0	697,0	697,0	975,0	975,0	1393,0
152	515,0	736,0	736,0	1030,0	1030,0	1471,0
157	542,0	775,0	775,0	1085,0	1085,0	1550,0
162	570,0	815,0	815,0	1140,0	1140,0	1630,0



CONVERSION TABLES FOR USE WITH CHAPTERS P AND Q

TABLE P AND Q, A1.8

CONVERSIONS FOR STUD LINK CHAIN CABLE—BRITISH UNITS

Conversion factors 1 inch = 25,4 mm

1 tonf = 1,016 tonne-f = 9,96 kN

CHAIN DIAMETER	GRADE					
	U 1		U 2		U 3	
	Proof Load	Breaking Load	Proof Load	Breaking Load	Proof Load	Breaking Load
inches	tonf	tonf	tonf	tonf	tonf	tonf
$\frac{1}{16}$	4.77	6.82	6.82	9.55	9.55	13.64
$\frac{1}{8}$	6.03	8.61	8.61	12.05	12.05	17.22
$\frac{3}{16}$	7.42	10.60	10.60	14.83	14.83	21.19
$\frac{1}{2}$	8.95	12.78	12.78	17.90	17.90	25.57
$\frac{5}{8}$	10.62	15.17	15.17	21.24	21.24	30.34
$\frac{3}{4}$	12.43	17.75	17.75	24.85	24.85	35.50
$\frac{7}{8}$	14.36	20.52	20.52	28.73	28.73	41.00
$1\frac{1}{16}$	16.44	23.49	23.49	32.88	32.88	46.97
1	18.65	26.65	26.65	37.30	37.30	53.30
$1\frac{1}{8}$	23.50	33.50	33.50	46.90	46.90	67.00
$1\frac{1}{4}$	26.05	37.25	37.25	52.10	52.10	74.45
$1\frac{3}{8}$	28.80	41.15	41.15	57.60	57.60	82.25
$1\frac{1}{2}$	31.65	45.20	45.20	63.30	63.30	90.40
$1\frac{7}{8}$	37.70	53.90	53.90	75.45	75.45	107.80
$1\frac{1}{2}$	40.95	58.50	58.50	81.90	81.90	117.00
$1\frac{5}{8}$	44.30	63.30	63.30	88.60	88.60	126.60
$1\frac{3}{4}$	47.75	68.25	68.25	95.50	95.50	136.45
$1\frac{7}{8}$	55.05	78.65	78.65	110.10	110.10	157.25
$1\frac{1}{2}$	58.85	84.10	84.10	117.70	117.70	168.15
$1\frac{3}{4}$	62.80	89.70	89.70	125.60	125.60	179.40
2	71.00	101.40	101.40	142.00	142.00	202.85
$2\frac{1}{16}$	75.26	107.51	107.51	150.50	150.50	215.00
$2\frac{1}{8}$	79.63	113.75	113.75	159.25	159.25	227.50
$2\frac{1}{4}$	84.10	120.15	120.15	168.25	168.25	240.30
$2\frac{3}{8}$	93.40	133.45	133.45	186.80	186.80	266.85
$2\frac{1}{2}$	98.20	140.30	140.30	196.40	196.40	280.55
$2\frac{7}{8}$	103.10	147.30	147.30	206.20	206.20	294.55
$2\frac{1}{2}$	108.10	154.45	154.45	216.20	216.20	308.85
$2\frac{3}{4}$	118.40	169.15	169.15	236.80	236.80	338.30
$2\frac{1}{2}$	123.70	176.70	176.70	247.40	247.40	353.40
$2\frac{3}{4}$	129.10	184.40	184.40	258.20	258.20	368.85
$2\frac{7}{8}$	140.15	200.25	200.25	280.35	280.35	400.45
3	151.60	216.60	216.60	303.20	303.20	433.15
$3\frac{1}{16}$	157.45	224.95	224.95	314.90	314.90	449.85
$3\frac{1}{8}$	169.40	242.05	242.05	338.85	338.85	484.05
$3\frac{1}{4}$	181.75	259.60	259.60	363.45	363.45	519.25
$3\frac{3}{8}$	194.35	277.70	277.70	388.75	388.75	555.35
$3\frac{1}{2}$	207.35	296.20	296.20	414.65	414.65	592.35
$3\frac{5}{8}$	213.95	305.60	305.60	427.85	427.85	611.25
$3\frac{3}{4}$	227.35	324.80	324.80	454.70	454.70	649.55
$3\frac{7}{8}$	234.64	335.25	335.25	469.33	469.33	670.50
$3\frac{1}{2}$	248.05	354.33	354.33	496.06	496.06	708.65
4	255.05	364.35	364.35	510.15	510.15	728.75
$4\frac{1}{8}$	269.35	384.75	384.75	538.65	538.65	769.50
$4\frac{1}{4}$	227.89	397.00	397.00	555.77	555.77	793.95
$4\frac{3}{8}$	298.65	426.65	426.65	597.30	597.30	853.25
$4\frac{1}{2}$	313.70	448.10	448.10	627.35	627.35	896.20
$4\frac{3}{4}$	328.90	469.90	469.90	657.85	657.85	939.80
$4\frac{7}{8}$	344.40	492.00	492.00	688.80	688.80	984.00
$4\frac{1}{2}$	351.25	501.78	501.78	702.49	702.49	1000.36
$4\frac{7}{8}$	361.01	515.73	515.73	722.03	722.03	1031.47
5	376.02	537.18	537.18	752.06	752.06	1074.36
$5\frac{1}{8}$	391.21	558.87	558.87	782.42	782.42	1117.74
$5\frac{1}{4}$	401.42	573.45	573.45	802.83	802.83	1146.91
$5\frac{3}{8}$	427.23	610.33	610.33	854.46	854.46	1220.66
$5\frac{1}{2}$	453.43	647.75	647.75	906.85	906.85	1295.51
$5\frac{3}{4}$	479.96	685.66	685.66	959.93	959.93	1371.34
6	506.80	724.00	724.00	1013.61	1013.61	1448.01
$6\frac{1}{8}$	588.93	762.76	762.76	1067.87	1067.87	1525.52
$6\frac{3}{8}$	561.25	801.79	801.79	1122.50	1122.50	1603.57

LLOYD'S REGISTER OF SHIPPING

TABLE P AND Q, A1.9

CONVERSION FOR EQUIVALENT ELONGATION ON  $5.65\sqrt{S_0}$  FOR TEST PIECES WITH  
A GAUGE LENGTH OF 2 INCHES AND CROSS-SECTIONAL AREA IN INCHES<sup>2</sup>

ACTUAL PERCENTAGE ELONGATION ON 2 IN GAUGE LENGTH	CORRESPONDING PERCENTAGE ELONGATION ON $5.65\sqrt{S_0}$ GAUGE LENGTH WHERE CROSS-SECTIONAL AREA IN INCHES <sup>2</sup> IS:—										
	0.05	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.0
18	22	19	16	15	14	14	13	13	12	12	12
19	23	20	17	16	15	14	14	13	13	13	13
20	24	21	18	17	16	15	15	14	14	13	13
21	25	22	19	18	17	16	15	15	14	14	14
22	26	23	20	18	17	17	16	16	15	15	15
23	28	24	21	19	18	17	17	16	16	15	15
24	29	25	22	20	19	18	18	17	17	16	16
25	30	26	23	21	20	19	18	18	17	17	17
26	31	27	24	22	21	20	19	18	18	18	17
27	32	28	25	23	21	20	20	19	19	18	18
28	34	29	26	24	22	21	20	20	19	19	19
29	35	30	26	24	23	22	21	21	20	20	19
30	36	31	27	25	24	23	22	21	21	20	20
31	37	32	28	26	25	24	23	22	21	21	20
32	38	33	29	27	25	24	23	23	22	22	21
33	40	34	30	28	26	25	24	23	23	22	22
34	41	36	31	29	27	26	25	24	23	23	22
35	42	37	32	29	28	27	26	25	24	24	23
36	43	38	33	30	29	27	26	26	25	24	24
37	44	39	34	31	29	28	27	26	26	25	24
38	46	40	35	32	30	29	28	27	26	26	25
39	47	41	36	33	31	30	29	28	27	26	26
40	48	42	36	34	32	30	29	28	28	27	26
41	49	43	37	34	33	31	30	29	28	28	27
42	50	44	38	35	33	32	31	30	29	28	28
43	52	45	39	36	34	33	31	30	30	29	28
44	53	46	40	37	35	33	32	31	30	30	29
45		47	41	38	36	34	33	32	31	30	30
46		48	42	39	36	35	34	33	32	31	30
47		49	43	39	37	35	34	33	32	32	31



CONVERSION TABLES FOR USE WITH CHAPTERS P AND Q

TABLE P AND Q, A1.10

CONVERSION FOR EQUIVALENT ELONGATION ON  $5.65\sqrt{S_0}$  FOR TEST PIECES WITH  
A GAUGE LENGTH OF 8 INCHES AND CROSS-SECTIONAL AREA IN INCHES<sup>2</sup>

ACTUAL PERCENTAGE ELONGATION ON 8 IN GAUGE LENGTH	CORRESPONDING PERCENTAGE ELONGATION ON $5.65\sqrt{S_0}$ GAUGE LENGTH WHERE CROSS-SECTIONAL AREA IN INCHES <sup>2</sup> IS:—																
	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.0	1.2	1.4	1.6	1.8	2.0	3.0	4.0
10	18	16	15	14	13	13	12	12	12	11	11	11	10	10	10	9	9
11	20	18	16	15	15	14	14	13	13	13	12	12	12	11	11	10	10
12	22	19	18	17	16	15	15	14	14	14	13	13	13	12	12	11	10
13	24	21	19	18	17	17	16	16	15	15	14	14	14	13	13	12	11
14	25	22	20	19	18	18	17	17	16	16	15	15	15	14	14	13	12
15	27	24	22	21	20	19	19	18	18	17	17	16	16	15	15	14	13
16	29	26	23	22	21	20	20	19	19	18	18	17	17	16	16	15	14
17	31	27	25	23	22	22	21	20	20	19	19	18	18	17	17	16	15
18	33	29	26	25	24	23	22	22	21	21	20	19	19	18	18	17	16
19	35	30	28	26	25	24	23	23	22	22	21	20	20	19	19	18	17
20	36	32	29	28	26	26	25	24	23	23	22	21	21	20	20	18	17
21	38	34	31	29	28	27	26	25	25	24	23	23	22	21	21	19	18
22	40	35	32	30	29	28	27	26	26	25	24	24	23	22	22	20	19
23	42	37	34	32	30	29	28	28	27	26	25	25	24	23	23	21	20
24	44	38	35	33	32	31	30	29	28	28	27	26	25	25	24	22	21
25	45	40	37	34	33	32	31	30	29	29	28	27	26	26	25	23	22
26	47	42	38	36	34	33	32	31	31	30	29	28	27	27	26	24	23
27	49	43	40	37	36	34	33	32	32	31	30	29	28	28	27	25	24
28	51	45	41	39	37	36	35	34	33	32	31	30	29	29	28	26	24
29	53	46	42	40	38	37	36	35	34	33	32	31	30	30	29	27	25
30		48	44	41	40	38	37	36	35	34	33	32	31	31	30	28	26
31		50	45	43	41	40	38	37	36	36	34	33	32	32	31	29	27
32		51	47	44	42	41	39	38	38	37	35	34	33	33	32	30	28
33		53	48	45	43	42	41	40	39	38	37	35	34	34	33	30	29
34			50	47	45	43	42	41	40	39	38	36	36	35	34	31	30
35			51	48	46	45	43	42	41	40	39	38	37	36	35	32	31
36			53	50	47	46	44	43	42	41	40	39	38	37	36	33	32
37				51	49	47	46	44	43	42	41	40	39	38	37	34	33
38				52	50	48	47	46	45	44	42	41	40	39	38	35	34
39					51	50	48	47	46	45	43	42	41	40	39	36	35

## APPENDIX 2

## LISTS OF APPROVED MANUFACTURERS AND PROVING ESTABLISHMENTS

## STEEL MANUFACTURERS

The following establishments have complied with the requirements for quality and testing of steel and have been recognized by the Committee.

## FIRMS IN GREAT BRITAIN AND IRELAND

Alston Foundry Co., Ltd., Nent Force Foundry, Alston, Cumberland. (*Small castings*)  
 Baker, W. A., & Co., Ltd., Westgate Works, Newport, Mon. (*Castings*)  
 Baker Perkins, Ltd., Peterborough. (*Small castings*)  
 Beardmore, William, & Co., Ltd., Parkhead, Glasgow. (*Forgings*)  
 Blackett, Hutton & Co., Ltd., Cleveland Steel Foundry, Guisborough, Yorkshire. (*Castings*)  
 Blair, George, & Co., Ltd., Armond Carr Works, Tow Law, Co. Durham. (*Castings*)  
 Blair, George & Co., Ltd., Newcastle Alloy Steel Foundry, Newcastle upon Tyne. (*Small castings*)  
 Bond's Foundry Co., Ltd., Tow Law, Co. Durham. (*Small castings*)  
 British Rail Engineering Ltd., Chester Bridge Works, Crewe. (*Castings*)  
 British Rolling Mills, Ltd., Brymill Works, Tipton, Staffs. (*Cold drawn bright bars*)  
 British Steel Corporation.

General Steels Division. Divisional Headquarters—Glasgow  
 Divisional Office (Teesside)—Middlesbrough

## Works:—

Appleby Frodingham, Scunthorpe, Lines. (*Ingots, slabs, blooms, billets, plates, sections, bars and rods*)  
 Barrow, Barrow-in-Furness, Lancashire. (*Billets, bars and sections*)  
 Cargo Fleet, Middlesbrough. (*Sections and bars*)  
 Consett, Consett, Durham. (*Plates*)  
 Clydebridge, Cambuslang, near Glasgow. (*Plates*)  
 Dalzell, Motherwell, Lanarkshire. (*Plates, sections, bars and blooms*)  
 East Moors, Cardiff. (*Ingots, blooms and billets*)  
 Glengarnock, Glengarnock, Ayrshire. (*Sections and bars*)  
 Hartlepool, Hartlepool, Co. Durham. (*Plates*)  
 Jarrow, Jarrow-on-Tyne. (*Rolling mill for sections and flats*)  
 Lanarkshire, Motherwell, Lanarkshire. (*Sections*)  
 Monks Hall and Co., Warrington. (*Rolling mill for bars and sections*)  
 Shelton, Stoke-on-Trent. (*Ingots, billets, bars and sections*)  
 Skinningrove, Saltburn-by-the-Sea. (*Sections and bars*)  
 South Teesside, Middlesbrough.

Cleveland. (*Sections and bars*)

Lackenby. (*Ingots, billets, sections, bars, strips and plates*)

Victoria, Coatbridge, Lanarkshire. (*Sections and bars*)

Warrington, Warrington, Lancs. (*Rolling mills for sections and bars*)

Workington, Workington, Cumberland. (*Rolling mill for bars and sections*)

Strip Mills Division. Divisional Headquarters—Cardiff.

## Works:—

Lancashire and Corby, Corby, Northants. (*Ingots, billets, slabs and strips*)

Llanwern, Newport, Mon. (*Light plates*)



## APPROVED MANUFACTURERS AND PROVING ESTABLISHMENTS

- Narrow Strip Works Group, Whitehead Works, Newport, Mon. (*Rolling mill for strips, bars and sections*)  
 Port Talbot, Glam. (*Ingots, plates and strips*)  
 Ravenscraig, Ravenscraig, Lanarkshire. (*Ingots, rolled slabs and thin plates*)  
 Shotton, Shotton, Flints. (*Ingots, slabs and light plates*)  
 Special Steels Division. Divisional Headquarters—Sheffield.
- Works:—  
 Bilston, Wolverhampton and Birchley Works, Staffordshire. (*Tube ingots, billets and bars*)  
 Brymbo, Wrexham, Denbighshire. (*Electric steel for forgings and re-rolling*)  
 Craigneuk, Motherwell. (*Castings, forgings, billets and bars*)  
 Hallside, Glasgow. (*Castings and billets*)  
 Park Gate, Rotherham. (*Ingots, billets, bars and sections*)  
 River Don and Associated, Sheffield. (*Ingots, forgings, plates and castings*)  
 Steel Peech and Tozer, Rotherham. (*Ingots, blooms, bars, forgings and billets*)  
 Stocksbridge and Tinsley Park, Sheffield. (*Ingots, blooms, bars, billets and slabs*)  
 Toll Cross, Glasgow. (*Castings*)  
 Trafford Park, Manchester. (*Forged rings and blanks*)
- Tubes Division. Divisional Headquarters—Corby, Northants.
- Works:—  
 Corby, Northants. (*Ingots, billets, bars and strip for tubes*)  
 Clydesdale, Bellshill, Lanarkshire. (*Ingots, billets, slabs and strips for tubes*)
- Broadbent, H., & Son Ltd., Foundry Division of Dewrance Triangle Ltd., Ashton-under-Lyne. (*Small castings*)  
 Brockhouse Castings, Ltd., Wednesfield, Wolverhampton. (*Small castings*)  
 Brown Bayley Steels, Ltd., Sheffield. (*Ingots, forgings and bars*)  
 Brown, The David, Gear Industries, Ltd., (Foundry Division), Penistone, Yorks. (*Castings*)  
 Cameron Iron Works, Livingston, West Lothian. (*Forgings*)  
 Catton & Co., Ltd., Pontefract Lane, Leeds. (*Castings*)  
 Coghlan Forge & Rolling Mills, Ltd., and Coghlan Bright Steel, Ltd., Hunslet Forge, Leeds. (*Rolling mills for bars*)  
 Cruikshank & Co., Ltd., Denny Iron Works, Denny, Stirlingshire. (*Small castings*)  
 Dunford Hadfields, Ltd., East Hecla Works, Sheffield. (*Ingots, blooms, billets, forgings, bars and special sections*)  
 Duport Steelworks Ltd.,  
 Briton Ferry Works, Briton Ferry, Neath. (*Ingots*)  
 Llanelli Works, Llanelli. (*Billets and bars*)  
 Edgar Allen Foundry, Ltd., Imperial Steel Works, Tinsley, Sheffield 9. (*Castings*)  
 Exors. of James Mills, Ltd., Bredbury Steel Works, Woodley, Stockport. (*Rolling mills for bars*)  
 Firth Brown Castings, Ltd.,  
 Atlas Works, Sheffield. (*Ingots, forgings, rolled bars and billets*)  
 Epok Works, Scunthorpe, South Humberside. (*Castings*)  
 Flather Halesowen, Ltd., Halesowen, near Birmingham. (*Cold drawn bright bars*)  
 GKN (South Wales), Ltd., Cardiff.  
 Castle Works. (*Rolling mills for bars and strips*)  
 Tremorfa Works. (*Rolling mills for bars and sections*)  
 Glanmorfa, Ltd., Llanelly. (*Castings and ingots*)  
 Glynwed Foundries, Ltd., Larkhall Steel Foundry, Lanarkshire. (*Castings*)  
 Goodwin Steel Castings, Ltd., Stoke-on-Trent. (*Castings*)  
 Hamilton, A., & Sons Ltd., Victoria Foundry, East Moors, Cardiff. (*Small castings*)  
 Head, Wrightson Foundries, Ltd., Steelcast Division:  
 Haverton Hill Road, Billingham, Cleveland. (*Castings*)  
 Light Pipe Hall Road, Stockton, Cleveland. (*Castings*)  
 Stockton Foundries, Teesdale Works, Thornaby, Cleveland. (*Castings*)  
 Holcroft Castings & Forgings, Ltd., Thornbury, Bradford. (*Castings*)  
 Hopkinsons, Ltd., Britannia Works, Huddersfield, Yorkshire. (*Castings*)

# LLOYD'S REGISTER OF SHIPPING

- Hyde, Robert & Son, Ltd.,  
Registered Office & Works: North Stafford Steel Foundry, Stoke-on-Trent.  
Foundry and Works: Clarendon, Chesterfield. (*Small castings*)
- Jopling, E., & Sons, Ltd., Pallion, Sunderland. (*Castings*)
- K. & L. Steelfounders & Engineers Limited, Letchworth, Hertfordshire. (*Castings*)
- Kirkstall Forge Engineering, Ltd., Leeds. (*Forgings*)
- Lake & Elliot, Ltd., Engineers and Founders, Braintree, Essex. (*Small castings*)
- Lee Bright Bar Ltd., Latchford, Warrington. (*Cold drawn bright bars*)
- Lilleshall Steel Ltd., Priors Lee, Telford. (*Rolling mills for sections and bars*)
- Lloyd, F. H., & Co., Ltd.,  
James Bridge, near Wednesbury, Staffordshire. (*Ingots and castings*)
- Lloyds (Burton) Ltd., Wellington Works, Burton upon Trent, Derbyshire. (*Ingots and castings*)
- Lloyds (Darlington) Ltd., Darlington. (*Small castings*)
- Martins (Dundyvan), Ltd., Coatbridge, Lanarkshire. (*Rolling mills for sections*)
- Mather & Platt, Ltd., Park Works, Manchester. (*Castings*)
- National Steel Foundry (1914), Ltd., The, Kirkland Works, Leven, Fifeshire. (*Castings*)
- North British Steel Group Ltd., Bathgate Road, West Lothian.  
Armada Works, (*Castings*)  
Bathgate Works, (*Castings*)
- O. H. Steel Founders and Engineers Ltd., Sheffield. (*Castings*)
- Parker Foundry Ltd., Mansfield Road, Derby. (*Small castings*)
- Patent Shaft Steel Works, Ltd., Wednesbury, Staffordshire.
- Raine & Co., Ltd., Delta Iron & Steel Works, Derwenthaugh, Newcastle upon Tyne. (*Rolling mills for sections and bars*)
- Redhough Iron & Steel Co. (1936), Ltd., Teams, Gateshead-on-Tyne. (*Rolling mills*)
- Renton & Fisher, Ltd., Hopetoun Steel Works, Bathgate. (*Castings*)
- Round Oak Steel Works, Ltd., Brierley Hill, Staffordshire. (*Ingots, blooms, billets, bars and sections*)
- Royal Ordnance Factory, Patricroft, Manchester. (*Ingots*)
- Ryder Brothers, Ltd. (Beehive Steel Foundry), Bolton. (*Castings*)
- Shaw, W., & Co., Ltd., Wellington Cast Steel Foundry, Middlesbrough. (*Castings*)
- Spartan Steel and Alloys Ltd., Spartan Works, Birmingham 6. (*Ingots*)
- Spear & Jackson, Ltd., Sheffield. (*Ingots and billets*)
- Tennent, R. B., Ltd., Whifflet Foundry, Coatbridge. (*Ingots*)
- Vickers Ltd., Shipbuilding Group, Barrow Engineering Works, Barrow-in-Furness. (*Forgings*)
- Williams, John, (Wishaw), Ltd., Excelsior Iron & Steel Works, Wishaw, Lanarkshire. (*Rolling mills for thin plates*)
- Wilson's Foundry & Engineering Co., Ltd., Bishop Auckland, Co. Durham. (*Castings*)
- Wolsingham Steel Co. Ltd., Wolsingham, Bishop Auckland, Co. Durham. (*Ingots and castings*)
- Irish Republic.  
Irish Steel Holdings Ltd., Haulbowline, Co. Cork. (*Ingots, bars and sections*)



# APPROVED MANUFACTURERS AND PROVING ESTABLISHMENTS

## FIRMS IN COUNTRIES OTHER THAN GREAT BRITAIN AND IRELAND (ALPHABETICALLY ARRANGED)

Note. The place of residence of the Surveyor giving attendance at each works is shown in parentheses.

- A.I. Steel & Iron Foundry (Vancouver), Ltd., Vancouver, B.C. (*Small castings*) (VANCOUVER)
- A.G. der Dillinger Huttenwerke, Dillingen/Saar, Federal Republic of Germany. (*Ingots and plates*) (SAARBRÜCKEN)
- A.S.S.A. Acciaierie di Susa Società Anonima, Turin, Italy. *Head Office*: Turin. *Works*: Susa. (*Castings*) (GENOA)
- A.V.E.G. S.p.A. (Acciaierie Valbruna Ernesto Gresele), Vicenza, Italy. (*Castings, bars, sections and forgings*) (VENICE)
- Acciaieria Fonderia Cividale, S.p.A., Cividale (Udine), Italy. (*Ingots*) (TRIESTE)
- Acciaieria di Rubiera S.a.s., Rubiera (Reggio Emilia), Italy. (*Ingots*) (MILAN)
- Acciaierie di Piombino,  
Stabilimento di Portovecchio di Piombino. (*Ingots, blooms, sections and bars*) (LEGHORN)
- Acciaierie e Tubificio, Meridionali, S.p.A., Bari, Italy. (*Castings and seamless tubes*) (NAPLES)
- Acerias Bragado S.A.I.C. and Aceros Bragado S.A.I.C., Bragado, Argentina. (*Castings*) (BUENOS AIRES)
- Acerias y Forjas de Azcoitia, Azcoitia Guipuzcoa, Spain. (*Ingots and small rolled bars*) (BILBAO)
- Aceros de Galicia, Vigo Spain. (*Castings*) (VIGO)
- Aceros y Fundiciones del Norte Pedro Orbegoza y Cia., S.A., Hernani, (Guipuzcoa), Spain. (*Ingots, forgings and rolled bars*) (BILBAO)
- Aciéries de Bordeaux, 33 Pessac, France. (*Castings*) (NANTES)
- Aciéries du Furan, 42 St. Etienne, France. (*Electric steel castings*) (LYONS)
- Aciéries & Fonderies de l'Est, France.  
Usine de Colombier-Fontaine. (*Small Castings*) (NANCY)  
Usine de Sainte-Suzanne. (*Castings*) (NANCY)
- Aciéries Leonard-Giot-Allard S.A., Turnhout, Belgium. (*Small castings*) (ANTWERP)
- Acindar S.A., Planta de Aceros Finos y Especiales, Villa Constitucion, Santa Fe, Argentina. (*Ingots, forgings and forged bars*) (BUENOS AIRES)
- Acos Villares, S.A. São Caetano do Sul, São Paulo, Brazil. (*Castings, forgings, billets and bars*) (SAO PAULO)
- Ahlström, A., Osakeyhtio, Karhulan Tehtaat, Karhula, Finland. (*Castings*) (HELSINKI/HELSINGFORS)
- Aichi Steel Works, Ltd.  
Chita Plant, Tokai, Japan. (*Ingots and bars*) (NAGOYA)  
Kariya Plant, Kariya, Japan. (*Ingots and bars*) (NAGOYA)
- Akimoku Steel Castings Co. Ltd., Noshiro-City, Japan. (*Castings*) (YOKOHAMA)
- Akita Kinzoku Kogyo Co. Ltd., Akita, Japan. (*Castings*) (YOKOHAMA)
- Aktiebolaget Jarnforadling, Hälleforsnas, Sweden. (*Small castings*) (STOCKHOLM)
- Albert Hoffmann K.G., Eschweiler, Federal Republic of Germany. (*Small ingots, forgings and castings*) (COLOGNE)
- Algoma Steel Corporation, Ltd., Sault St. Marie, Ontario, Canada. (*Plates, sections and bars*) (TORONTO)
- Allard, Usines & Aciéries, Société Anonyme, Mont-sur-Marchienne, near Charleroi, Belgium. (*Castings*) (ANTWERP)
- Allard, Usines & Aciéries, Société Anonyme, Turnhout, Belgium. (*Small castings*) (ANTWERP)
- Altos Hornos de Mexico, S.A., (A.H.M.S.A.), Monclova, Coah., Mexico. (*Plates*) (MEXICO CITY)
- Ampo S.C.I., Idiazabal, Guipuzcoa, Spain. (*Castings*) (BILBAO)
- Amsco Italiana S.p.A., Milan, Italy. (*Small castings*) (MILAN)
- Amurrio, S.A., Talleres de., Amurrio, Alava, Spain. (*Steel castings*) (BILBAO)
- Ando Iron Works Co., Ltd., Tokyo, Japan. (*Small forgings*) (YOKOHAMA)
- ARANZABAL S.A., Vitoria, Alava, Spain. (*Small castings*) (BILBAO)
- "A R B E D", Aciéries Réunies de Burbach-Eich-Dudelange,  
Division de Differdange, Differdange, Luxembourg. (*Sections and bars*) (NANCY)  
Division de Dommeldange, Dommeldange, Luxembourg. (*Ingots, forgings and castings*) (NANCY)  
Division d'Esch-Belval, Esch-sur-Allzette, Luxembourg. (*Ingots, blooms, billets, bars, angle bars, and sections*) (NANCY)  
Division d'Esch-Schifflange, Esch-sur-Allzette, Luxembourg. (*Ingots, bars and sections*) (NANCY)
- Armco Steel Corporation, Houston Plant, Texas, U.S.A. (*Plates and sections*) (CLEVELAND)
- Asano Tekkosho Co. Ltd., Saijo, Japan. (*Small forgings*) (KOBE)
- Associated Steel Foundries Co. Ltd., Natanya, Israel. (*Castings*) (HAIFA)
- Astilleros Españoles S.A.,  
Factoria de Asua (near Bilbao), Vizcaya, Spain. (*Castings*) (BILBAO)  
Factoria de Manises, Valencia, Spain. (*Castings*) (VALENCIA)  
Factoria de Reinos, Spain. (*Ingots, forgings, castings, plates and sections*) (BILBAO)
- Astilleros Rio Santiago Ensenada, Buenos Aires, Argentina. (*Steel castings*) (BUENOS AIRES)
- Astilleros y Talleres del Noroeste S.A., El Ferrol del Caudillo, Spain. (*Small forgings and small castings*) (EL FERROL)



# LLOYD'S REGISTER OF SHIPPING

- Atlantic Steel Castings Co., The, Chester, Pa., U.S.A. (*Castings*) (PHILADELPHIA)
- Atlas Steels Company, Welland, Ontario, Canada. (*Ingots and bars*) (TORONTO)
- Aubert et Duval, Ets., Aciéries des Ancizes, Les Ancizes, France. (*Ingots, rolled bars and forgings*) (LYONS)
- August Thyssen - Hutte A.G., Duisburg - Hamborn, Federal Republic of Germany.  
Area Hamborn. Steelworks Beeckerwerth, Bruckhausen and Ruhrort. (*Ingots, billets, slabs, plates and sections*) (DUSSELDORF)  
Duisburg-Huttenheim. (*Plates*) (DUSSELDORF)
- Australian Iron & Steel, Pty., Ltd.,  
Port Kembla, N.S.W. (*Plates, bars, sections and forgings*) (PORT KEMBLA)  
Steelworks, Kwinana, Western Australia. (*Small bars and sections*) (FREMANTLE)
- d'Auxonne, Acieries & Fonderies, 21 Auxonne, France. (*Small castings*) (LYONS)
- Avesta Jernverks Aktiebolag, Avesta, Sweden. (*Plates, sections and castings*) (STOCKHOLM)
- Azma S.A., Getafe, Madrid, Spain. (*Bars and sections*) (BILBAO)
- Babcock & Wilcox, Sociedad Espanola de Construcciones. *Head Office*: Calle Ercilla 1, Bilbao, Spain.  
*Works*: Galindo-San Salvador Del Valle, Vizcaya, Spain. (*Castings, ingots and forgings*) (BILBAO)
- Bakker, N.V., Machinefabriek-Staalgieterij, Ridderkerk, Holland. (*Ingots and castings*) (ROTTERDAM)
- Bendix Skagit Corporation, Sedro Woolley, Washington, U.S.A. (*Castings*) (SEATTLE)
- Bergische Stahlindustrie K.G., Remscheid, Federal Republic of Germany. (*Castings*) (DUSSELDORF)
- Bertoli S.p.A., Officine Fratelli Bertoli fu Rodolfo, Udine, Italy. (*Castings, forgings, bars and sections*) (TRIESTE.)
- Bethlehem Steel Corporation,  
Bethlehem, Pa., U.S.A. (*Ingots, forgings, bars and sections*) (PHILADELPHIA)  
Burns Harbour Plant, Chesterton, Indiana, U.S.A. (*Rolling mills for plates*) (CHICAGO)  
Johnstown Plant, Johnstown, Pa., U.S.A. (*Ingots, billets, slabs, plates and bars*) (CLEVELAND)  
Lackawanna, N.Y., U.S.A. (*Ingots, blooms, billets, bars, plates and sections*) (CLEVELAND, O.)  
Lebanon, Pa., U.S.A. (*Rolling mills for bars and rivets*) (PHILADELPHIA)  
Seattle, Wash., U.S.A. (*Sections, bars and narrow flats*) (SEATTLE)  
Sparrows Point, Md., U.S.A. (*Plates*) (BALTIMORE)  
Steelton, Pa., U.S.A. (*Castings*) (PHILADELPHIA)
- Bharat Forge Company Ltd., Mundhwa, Poona, India. (*Forgings*) (POONA)
- Bhartia Electric Steel Co., Ltd., Calcutta, India. (*Castings*) (CALCUTTA)
- Birdsboro Corporation, Birdsboro, Pa., U.S.A. (*Castings*) (PHILADELPHIA)
- Bischoff-Werke K.G., Abt. Stahlgiesserei Ludinghausen/Westphalia, Federal Republic of Germany. (*Castings*) (DORTMUND)
- Björneborgs Jernverks Aktiebolag, Björneborg, Sweden. (*Ingots and forgings*) (GOTHENBURG)
- Black Clawson-Kennedy, Owen Sound, Ontario, Canada. (*Castings*) (TORONTO)
- Blanc-Misseron, Société Française des Aciéries de Quievrechain, (Nord), France. (*Ingots and castings*) (VALENCIENNES)
- Boel, Usines Gustave, Soc. An., La Louvière, Belgium. (*Ingots, forgings, castings, plates and universal flats*) (ANTWERP)
- Boetticher y Navarro S.A., Carretera de Andalucia KM9, Villaverde-Madrid, Spain. (*Small castings*) (MADRID)
- Bofors, Aktiebolaget, Bofors, Sweden. (*Ingots, forgings, castings and rolled bars*) (GOTHENBURG)
- Böhler, Gebr. & Co., Aktiengesellschaft, Vienna, Austria.  
*Works*: Bohlerwerk, Low Austria. (*Small forgings*) (VIENNA.)  
*Works*: Bruckbach, Low Austria. (*Rolling mills for sections and bars*) (VIENNA)  
*Works*: Kapfenberg, Styria. (*Ingots, castings, forgings, bars and plates*) (VIENNA)
- Bolzano, S.p.A. Acciaierie di, Bolzano, Italy. (*Ingots, billets, bars and forgings*) (VENICE)
- Boom, Travaux Métalliques de, Société Anonyme, Boom, Belgium. (*Small castings*) (ANTWERP)
- Borsig G.m.b.H., 1 Berlin-Tegel (Gruppe Deutsche Babcock), German Democratic Republic. (*Castings*) (BERLIN)
- Boschgotthardshutte, Otto Breyer G.m.b.H., Edelstahlwerk-Press-u. Hammerwerk-Mechanische Werkstätten, Huttental-Weidenau, Federal Republic of Germany. (*Ingots and forgings*) (DORTMUND)
- Boxholms A/B., Boxholm, Sweden. (*Ingots, rolled slabs, blooms, billets, sections and bars*) (STOCKHOLM)
- Bradford Kendall Ltd.  
*Works*: Adelaide, South Australia. (*Castings*) (ADELAIDE)  
*Works*: Alexandria, Sydney, N.S.W. (*Ingots and Castings*) (SYDNEY, N.S.W.)  
*Works*: Runcorn, Queensland. (*Castings*) (BRISBANE.)  
*Works*: South Beach, South Fremantle. (*Castings*) (FREMANTLE)
- Bradken Malaysia Sdn. Berhad, Lahat Papn Road, Ipoh, Perak, Malaysia. (*Castings*) (SINGAPORE)
- Breda Fucine S.p.A., Sesto San Giovanni, Milan, Italy. (*Forgings*) (MILAN)
- Breda Siderurgica Società per Azioni, Sesto San Giovanni, Milan, Italy. (*Ingots and sections*) (MILAN)



# APPROVED MANUFACTURERS AND PROVING ESTABLISHMENTS

Breitenbach, Ed., G.m.b.H., Huttental-Weidenau/Sieg, Federal Republic of Germany. (*Castings*) (DORTMUND)

Bremer Vulkan, Schiffbau und Maschinenfabrik, Bremen-Vegesack, Federal Republic of Germany. (*Castings*) (BREMEN)

Brescia, Acciaieria e Tubificio di, Società Anonima, Brescia, Italy. (*Ingots, sections, bars and castings*) (MILAN)

Broken Hill Proprietary Co., Ltd.

Iron & Steel Works, Newcastle, N.S.W. (*Ingots, billets, plates, sections, strip and castings*) (NEWCASTLE, N.S.W.)

Iron & Steel Works, Whyalla, S. Australia. (*Ingots, castings, bars and sections*) (WHYALLA)

Bulten-Kanthal AB, Kanthal-Divisionen, Hallstahammar, Sweden. (*Ingots, billets, bars and castings*) (STOCKHOLM)

Burlington Steel Company, Division of Slater Steel Industries, Ltd., Hamilton, Ontario, Canada. (*Small sections and bars*) (TORONTO)

A/S Burmeister & Wain, Motor-og Maskinfabrik af 1971, Copenhagen, Denmark. (*Ingots, forgings and castings*) (COPENHAGEN)

Burn & Co., Ltd., Howrah, India. (*Castings*) (CALCUTTA)

C.A.E. Machinery Ltd., Vancouver, B.C. (*Small castings*) (VANCOUVER)

Cabot Machinery Corp., Pampa, Texas. (*Forgings*) (HOUSTON)

Cameron Iron Works Inc., Houston, Texas. (*Ingots and forgings*) (GALVESTON)

Canada Forging Ltd., Welland, Ontario, Canada. (*Forgings*) (TORONTO)

Canadian Steel Foundries Division Hawker Siddeley Canada Ltd., Longue Pointe, Montreal, P.Q., Canada. (*Castings*) (MONTREAL)

Carlo Tassara, Stabilimenti Electrosiderurgioi S.p.A., Breno, Brescia, Italy. (*Ingots and small forgings*) (MILAN)

Ceretti, Pietro Maria, S.p.A., Ferriera Dell'Ossola-Villadossola, Italy. (*Castings*) (MILAN)

Charleroi, Société Anonyme de la Fabrique de Fer de, Charleroi, Belgium. (*Ingots, slabs and plates*) (ANTWERP)

Cheoy Lee Shipyard Lantau Island, Hong Kong. (*Castings*) (HONG KONG)

Chiers, Société des Hauts-Forneaux de la, Forges de Vireux Molhain, Vireux, Ardennes, France. (*Bars and sections*) (VALENCIENNES)

Chubu Steel Plate Co. Ltd., Nakagawa Works, Nagoya, Japan. (*Ingots and plates*) (NAGOYA)

Chubu Steel Tube Co. Ltd., Osaka, Japan. (*Seamless tubes*) (OSAKA)

Clabecq, Société Anonyme Forges de, Clabecq, Belgium. (*Ingots, plates, bars and sections*) (ANTWERP)

Cockerill-Ougrée-Providence, Rehon Works, Rehon, France. (*Strip*) (NANCY)

S.A. Cockerill-Ougrée-Providence-Esperance-Longdoz, Seraing, Belgium.

Group I: A—Departement Acieries et Laminiers d'Ougrée, Seraing. (*Ingots, blooms, billets, slabs and thin plates*) (ANTWERP)

B—Departement Acieries et Laminiers de Chertal. (*Ingots and thin plates*) (ANTWERP)

C—Departement Forges, Fonderies et Acierie Speciale. (*Castings and forgings*) (ANTWERP)

D—d'Hautmont, Nord France. (*Ingots and sections*) (VALENCIENNES)

Group Marchienne-Athus: S.A. Cockerill, Marchienne-au-Pont. (*Sections, bars, ingots and blooms*) (ANTWERP)

Colt Industries, Crucible Inc., P.O. Box 226, Midland, Pa. 1505g., U.S.A. (*Ingots, slabs, billets, hot rolled and cold drawn bars*) (CLEVELAND, O.)

Combinatul Siderurgic Gheorghiu-Dej, Galatz, Rumania. (*Plates*) (GALATZ)

"COMETNA" Companhia Metalurgica Nacional, S.A.R.L., Amadora, Portugal. (*Castings*) (LISBON)

Cominco Ltd., Trail, B.C., Canada. (*Castings*) (VANCOUVER)

Commonwealth Steel Co., Ltd., Lidcombe Works, Sydney, N.S.W. (*Castings*) (SYDNEY, N.S.W.)

Moorooka Works, Brisbane, Queensland. (*Castings*) (BRISBANE)

Waratah Works, Newcastle, N.S.W. (*Castings, forgings, ingots and bars*) (NEWCASTLE, N.S.W.)

Companhia Ferro e Aço de Vitoria, Vitoria, State of Espirito Santo, Brazil. (*Rolling mill for bars and sections*) (RIO DE JANEIRO)

Companhia Siderurgica Hime, Usina de Neves, Sao Goncal, Estado de Rio de Janeiro, Brazil. (*Ingots, sections and bars*) (RIO DE JANEIRO)

Companhia Siderurgica Nacional, Volta Redonda, Usina Presidente Vargas, Estado do Rio de Janeiro, Brazil. (*Plates and sections*) (RIO DE JANEIRO)

Compañia Auxiliar de Ferrocarriles, Beasain, Guipuzcoa, Spain. (*Small castings and forgings*) (BILBAO)

Construccion y Siderurgica Paulista, Cosipa, Cubatao, São Paulo, Brazil. (*Ingots and plates*) (SANTOS)

Cooperativa Industrial Electrodo y Aceros, Boó, Santander, Spain. (*Castings*) (BILBAO)

Crane Fisa S.A., Bilbao, Spain. (*Small castings*) (BILBAO)

Creusot Loire.

Branche Metallurgie, Groupe Transformation, Etablissement de l'Ondaine, Firminy, France. (*Ingots, billets, blooms, bars, castings and forgings*) (LYONS)

Division Mecanique Entreprises, Usines de St. Chamond 42-St. Chamond, France. (*Forgings*) (LYONS)

Division des Produits Laminés, Usine du Marais, 42-Saint Etienne, France. (*Slabs and billets*) (LYONS)



# LLOYD'S REGISTER OF SHIPPING

## Creusot Loire—continued

- Usine des Dunes, 59 Malo les Bains, France. (*Ingots, billets, blooms, bars and forgings*) (DUNKIRK)
- Usines d'Imphy-58, France. (*Ingots, forgings, bars and sections*) (LYONS)
- Usine de Pamiers, Pamiers, France. (*Forgings*) (MARSEILLES)
- Usines Schneider, Le Creusot, France. (*Ingots, forgings, castings, plates and sections*) (LYONS)
- Crucible Steel Company of Canada, Ltd., Sorel, P.Q., Canada. (*Ingots and forgings*) (MONTREAL)
- Dai Han Anchor Chain Mfg. Co. Ltd., Seoul, Korea. (*Castings*) (BUSAN)
- Daido Steel Co., Ltd.
- Chita Plant, Tokai, Japan. (*Ingots, billets, bars and forgings*) (NAGOYA)
- Hoshizaki Plant, Nagoya, Japan. (*Ingots and bars*) (NAGOYA)
- Shibukawa Works, Shibukawa, Japan. (*Ingots, small forgings and bars*) (YOKOHAMA)
- Tsukiji Plant, Nagoya, Japan. (*Ingots, forgings and castings*) (NAGOYA)
- Daitetsu Steel Industrial Co. Ltd., Osaka, Japan. (*Ingots and sections*) (OSAKA)
- Dalmine S.p.A. Head Office: Milan, Italy.
- Dalmine Costa Volpino, Bergamo. (*Seamless and welded tubes*) (MILAN)
- Dalmine Works, Bergamo. (*Ingots and seamless tubes*) (MILAN)
- Danske, (Det), Staalvalsevaerk A/S, Frederiksvaerk, Denmark. (*Plates, sections and bars*) (COPENHAGEN)
- Date Seiko Co. Ltd., Fukushima Prefecture, Japan. (*Castings*) (YOKOHAMA)
- Davies & Baird Pty. Ltd., Newlands Road, Coburg, Melbourne, Australia. (*Castings*) (MELBOURNE)
- De Laval Turbine Inc., Engine & Compressor Division, Oakland, Cal., U.S.A. (*Castings*) (SAN FRANCISCO)
- Decker, Gebrüder, Betrieb 1, Eisen- & Stahlgiesserei, Nürnberg 2, Ostendstr. 84, Federal Republic of Germany. (*Electric steel castings*) (AUGSBURG)
- Dembiermont & Cie., Maurice, Hautmont (Nord), France. (*Forgings*) (VALENCIENNES)
- Denizcilik Bankasi T.A.O., Halic Yard Foundry, Turkey. (*Castings*) (ISTANBUL)
- Deutsche Edelstahlwerke A.G., Krefeld, Federal Republic of Germany. (*Ingots, forgings and rolled materials*) (DUSSELDORF)
- Dijkers, G., & Co., N.V., Hengelo, Holland. (*Small castings*) (AMSTERDAM)
- Dingler, Karcher & Cie., G.m.b.H., Saarländisches Stahlwerk, Worms/Rhein, Federal Republic of Germany. (*Castings*) (MANNHEIM)
- Dominion Foundries & Steel Ltd., Hamilton, Ontario, Canada. (*Ingots, plates and castings*) (TORONTO)

- Dominion Steel & Coal Corporation Ltd.
- Montreal Works, 5870, St. Patrick Street, Montreal, Canada. (*Angles, bars and rivets*) (MONTREAL)
- Dongkuk Steel Mill Co. Ltd., Busan Works, Busan, Korea. (*Plates*) (BUSAN)
- Dorrenberg, Ed., Sohne Edelstahlwerke, Runderoth/Rheinland, Federal Republic of Germany. (*Castings*) (COLOGNE)
- Drammens Jernstoberi & Mek-Verksted, A/S, Drammen, Norway. (*Small castings*) (OSLO)
- Dunedin Engineering & Steel Co., Ltd., Dunedin, New Zealand. (*Castings*) (DUNEDIN)
- Dunswart Iron & Steel Works, Ltd., Benoni, South Africa. (*Castings, ingots, billets and small sections*) (VEREENIGING)
- Duro-Felguera, Sociedad Metalúrgica, La Felguera, Asturias, Spain. (*Castings*) (GIJON)
- Echevarria, Sociedad Anonima, Bilbao, Spain. (*Small sections and bars, small forgings and ingots*) (BILBAO)
- Echeverria, Patricio, S.A., Legazpia, Spain. (*Ingots, blooms, forgings and small bars*) (BILBAO)
- Edelstahlwerke Buderus A.G., Wetzlar, Federal Republic of Germany. (*Ingots, blooms, billets, bars and forgings*) (DORTMUND)
- Edelstahlwerk Witten A.G., Witten-Ruhr, Federal Republic of Germany. (*Ingots, billets, bars, forgings and narrow flats*) (DORTMUND)
- Edgewater Corporation, Oakmont, Pennsylvania, U.S.A. (*Ingots and forgings*) (CLEVELAND)
- Egyptian Iron & Steel Co., S.A.E., Helwan, Arab Republic of Egypt. (*Plates*) (ALEXANDRIA)
- Eisen-und Stahlwerke Oehler & Co. A.G., Aarau, Switzerland. (*Castings*) (WINTERTHUR)
- Eisen-und Stahlwerk Pleissner G.m.b.H., Herzberg/Harz, Federal Republic of Germany. (*Castings*) (HANNOVER)
- Eisenwerk Bohmer, Witten, Ruhr, Dortmund, Federal Republic of Germany. (*Castings*) (DORTMUND)
- Eisenwerk Breitenfeld Ges. m.b.H., Mitterdorf/Murztal, Austria. (*Forgings*) (VIENNA)
- Eisenwerk Geweke, R. & C. R. Lange K.G., Hagen-Haspe, Federal Republic of Germany. (*Electric steel castings*) (DORTMUND)
- Eisenwerk Rödinghausen K.G., Lendringsen Krs., Iserlohn, Federal Republic of Germany. (*Castings*) (DORTMUND)
- Electrosteel Castings Ltd., Khardah, West Bengal, India. (*Castings*) (CALCUTTA)
- Elkem-Spigerverket A/S, Christiania Spigerverk, Oslo, Norway. (*Ingots and bars, also rivet bars*) (OSLO)
- Ellerbrock, Hans, Stahlgiesserei und Maschinenfabrik, Hamburg, Federal Republic of Germany. (*Castings*) (HAMBURG)
- Empire Steel Castings Inc., Reading, Pa., U.S.A. (*Castings*) (PHILADELPHIA)
- Empresa Nacional Bazan, El Ferrol del Caudillo, Spain. (*Castings*) (EL FERROL)



# APPROVED MANUFACTURERS AND PROVING ESTABLISHMENTS

- Empresa Nacional Siderurgica, S.A., (ENSIDESA),  
Factoria de Aviles, Spain. (*Ingots, slabs and billets for re-rolling, plates and sections*) (GIJON)
- Fabrica de Gijon, Gijon, Spain. (*Rivet bars and ingots*) (GIJON)
- Fabrica de La Felguera, Asturias, Spain. (*Ingots, billets, plates and sections*) (GIJON)
- Fabrica de Mieres, Asturias, Spain. (*Sections, bars and plates up to 15 mm. in thickness*) (GIJON)
- Factoria de Verina-Gijon, Spain. (*Ingots, billets, slabs and plates*) (GIJON)
- Empresa Siderurgica del Peru, Siderperu, Chimbote, Peru. (*Plates*) (CALLAO)
- Endo Co. Ltd., Osaka, Japan. (*Forgings*) (OSAKA)
- Equimetal-Empresa Fabril de Equipamentos Metalicos S.A.R.L., Portugal. (*Castings*) (LISBON)
- Eregli Demir ve Celik Fabrikalari T.A.S., Eregli, Turkey. (*Ingots and plates*) (ISTANBUL)
- Eschweiler Bergwerks-Verein Hüttenbetriebe, Eschweiler-Aue, Federal Republic of Germany. (*Ingots and seamless tubes*) (COLOGNE)
- Esco Ltd., Port Coquitlam, B.C., Canada. (*Castings*) (VANCOUVER)
- Estel, Hoesch Hüttenwerke, A.G., Dortmund, Federal Republic of Germany.
- Werk Phoenix Hörde, Dortmund-Hörde. (*Ingots, plates and castings*) (DORTMUND)
- Werk Union, Dortmund. (*Bars and sections*) (DORTMUND)
- Werk Westfalenhütte, Dortmund. (*Ingots, billets, plates, bars and sections*) (DORTMUND)
- Estel, Hoogovens Ijmuiden B.V., Ijmuiden, Holland. (*Plates and sections*) (AMSTERDAM)
- Utrecht, Holland. (*Rolling mills for bars*) (AMSTERDAM)
- Fagersta Aktiebolag, Fagersta, Sweden (Brukskoncernen).
- Works: Fagersta. (*Blooms, billets, rolled bars and electric resistance welded tubes*) (STOCKHOLM)
- Works: Forsbacka. (*Blooms, billets, forged and rolled bars*) (STOCKHOLM)
- Works: Osterbyverken, Osterbybruk. (*Castings, forgings and rolling mill for bars*) (STOCKHOLM)
- Faggian, Acciaierie Elettriche Pio, Soc. per Azioni, La Spezia, Italy. (*Small castings*) (LA SPEZIA)
- Falck, Acciaierie e Ferriere Lombarde. Head Office & Works: Milan, Italy. (*Weldless rolled or drawn tubes*) (MILAN)
- "Concordia". Works: Sesto San Giovanni. (*Ingots and plates*) (MILAN)
- "Unione". Works: Sesto San Giovanni. (*Ingots, sections, bars, forgings and castings*) (MILAN)
- Falk Corporation, Milwaukee, Wis., U.S.A. (*Castings*) (CHICAGO)
- Farrell-Cheek Steel Co., Sandusky, Ohio, U.S.A. (*Steel castings*) (CLEVELAND)
- Ferretera Montanesa S.A., Torrelavega, Spain. (*Castings*) (BILBAO)
- Ferrovorm, Ltd, Port Elizabeth, Foundry Division, South Africa. (*Small castings*) (PORT ELIZABETH)
- Ferry-Capitain S.A.R.L., Usines de Bussy-Joinville, France. (*Electric steel castings*) (NANCY)
- Feurs, Fonderies & Acieries Electriques de, Feurs, Loire, France. (*Small castings*) (MARSEILLES)
- FIAT, Società per Azioni, Sezione Ferriere Piemontesi, Turin, Italy. (*Ingots, plates, sections, also seamless and welded tubes*) (GENOA)
- Finkl, A., & Sons Company, Chicago, Ill., U.S.A. (*Forgings*) (CHICAGO)
- Fischer, George, Ltd., Schaffhausen, Switzerland. (*Castings*) (WINTERTHUR)
- Fit Ferrotubi-Fabbrica Italiana Tubi Ferrotubi, Italy. (*Ingots, billets and seamless tubes*) (GENOA)
- Fives-Lille-Cail, Société de., Usine de Denain, Denain (Nord), France. (*Castings, ingots, forgings, blooms, bars and sheets*) (VALENCIENNES)
- Flag S.p.A. Marcon (Mestre). (*Small castings*) (VENICE)
- Fomas-Forgiatura Moderna Acciai Speciali S.p.A., Osnago, (Como), Italy. (*Forgings*) (MILAN)
- Fonderia Acciaieria Giovanni Mandelli, Turin, Italy. (*Castings*) (GENOA)
- Fonderia Acciaio La Rapida, Olgiate Olona, Italy. (*Castings*) (MILAN)
- Fonderie de Fer et d'Aciers, Bienne-Biel, Switzerland. (*Castings*) (WINTERTHUR)
- Fonderies et Acieries de Provence, Marseilles, France. (*Castings*) (MARSEILLES)
- Fonderies Grandry, S.A., Mnoho (Ardenne), France. (*Castings*) (VALENCIENNES)
- Forjas Alavesas S.A., Vitoria, Spain. (*Ingots, rolled bars and forgings*) (BILBAO)
- Fried. Krupp Huttenwerke A.G., Bochum, Federal Republic of Germany.
- Works: Bochum. (*Ingots, plates, forgings, castings and bars*) (DUSSELDORF)
- Works: Rheinhausen. (*Ingots, bars and sections*) (DUSSELDORF)
- Friedrich-Carl-Hütte G.m.b.H., Delligsen über Alfeld/Leine, Federal Republic of Germany. (*Castings*) (HANNOVER)
- Fucine Meridionali, S.p.A., Bari, Italy. (*Castings and forgings*) (NAPLES)
- Fukushima Seiko Co., Ltd., Fukushima, Japan. (*Castings*) (YOKOHAMA)
- Funabashi Steel Works Ltd., Funabashi, Japan. (*Ingots and flat bars*) (YOKOHAMA)
- Funderia, S.A. de, Manresa, Spain. (*Castings*) (BARCELONA)
- Fundiacero S.A., Miranda de Ebro Works, Bilbao, Spain. (*Castings*) (BILBAO)
- Fundiciones Arriaran S.A., Lazcano, Guipuzcoa, Spain. (*Castings*) (BILBAO)



# LLOYD'S REGISTER OF SHIPPING

- Fundiciones del Estanda, S.A., Beasain, Spain. (*Castings*) (BILBAO)
- Fundiciones Echevarria S.A., Beasain, Guipuzcoa, Spain. (*Ingots, small rolled bars and castings*) (BILBAO)
- Fundiciones Ederra, Miranda del Ebro, Burgos, Spain. (*Castings*) (BILBAO)
- Fundiciones Especiales Zaragoza, S.A., Zaragoza, Spain. (*Castings*) (BILBAO)
- Fundicoes do Rossio de Abrantes, S.A.R.L., Rossio de Abrantes, Portugal. (*Castings*) (LISBON)
- Fundidora Monterrey, S.A., Monterrey, N.L., Mexico. (*Plates*) (MEXICO CITY)
- Ganz-Mavag Mozdony Vagon es Gepgyar, Budapest, Hungary. (*Castings and forgings*) (VIENNA)
- Garavaglia S.A.S., Caronno Pertusella, Italy. (*Castings*) (MILAN)
- Generale d'Hydraulique et de Mecanique Usine Metalurgique de Marquise, Rinxent, Pas de Calais, France. (*Castings*) (DUNKIRK)
- Gennevilliers, Aciéries de, Gennevilliers, Seine, France. (*Castings*) (PARIS)
- Godrej & Boyce Mfg. Co. Pvt. Ltd., Bombay, India. (*Steel castings*) (BOMBAY)
- Go Iron Works, Ltd., Tarui Works, Tarui, Japan. (*Small castings*) (NAGOYA)
- Gottwald, Leo, Werk Hattingen, Ruhr, Federal Republic of Germany. (*Small forgings*) (DORTMUND)
- Gränges Stål, Oxelösunds Järnverk, Oxelösund, Sweden. (*Ingots, rolled slabs and plates*) (STOCKHOLM)
- Grossmann, C., Eisen-und Stahlwerk A.G., Solingen-Wald, Federal Republic of Germany. (*Castings*) (DUSSELDORF)
- Gueugnon, Forges de, Gueugnon, (S & L), France. (*Rolling mill for plates*) (LYONS)
- Guivisa S.A., Basauri, Bilbao, Spain. (*Castings*) (BILBAO)
- Gussstahlwerk Carl Bönnhoff, Wetter/Ruhr, Federal Republic of Germany. (*Ingots and castings*) (DORTMUND)
- Gussstahlwerk Risch K.G., Bergisch-Gladbach, Federal Republic of Germany. (*Electric steel castings*) (COLOGNE)
- Gutehoffnungshütte Sterkrade A.G., Werk Sterkrade, Oberhausen-Sterkrade, Federal Republic of Germany. (*Forgings*) (DUSSELDORF)
- Hainaut-Sambre, Société Métallurgiques, S.A., Couillet, Belgium.  
     Division de Couillet. (*Ingots, blooms, sections, flats, forgings, castings and bars*) (ANTWERP)  
     Division de Montignies et Chatelineau. (*Rolling mill*) (ANTWERP)
- Haine St. Pierre et Lesquin, Aciéries de, Société Anonyme, Haine St. Pierre, Belgium. (*Castings*) (ANTWERP)
- Lesquin-lez-Lille (Nord), France. (*Castings*) (VALENCIENNES)
- Hakodate Dock Co., Ltd., Hakodate Shipyard, Hakodate, Japan. (*Small forgings and castings*) (YOKOHAMA)
- Hallstahammar Aktiebolag, Hallstahammar, Sweden. (*Bars*) (STOCKHOLM)
- Hamsa-Hierros y Aceros Moldeados S.A., Ermengarda, Barcelona, Spain. (*Forged bars*) (BARCELONA)
- Haneda Pipe Works Co., Ltd., Tokyo, Japan. (*Seamless tubes*) (YOKOHAMA)
- Hatakeyama Iron Works Co. Ltd., Higashi Komatsugawa Works, Tokyo, Japan. (*Small forgings*) (YOKOHAMA)
- Hawker Siddeley Canada Ltd., Trenton Works, Trenton, N.S. (*Forgings*) (HALIFAX, N.S.)
- Heavy Engineering Corp., Ltd., Foundry Forge Plant, P. O. Dhurwa, Ranchi, India. (*Castings and forgings*) (JAMSHEDPUR)
- Helsingors Skibsværft-og Maskinbyggeri A/S, Aktieselskabet, Elsinore, Denmark. (*Forgings and castings*) (COPENHAGEN)
- Henricot, Usines Emile, Court St. Etienne, Belgium. (*Castings*) (ANTWERP)
- Herchamet S.A.I.C., Fundicion Electrica de Aceros Velez Sarfield, Rosario, Argentina. (*Castings*) (BUENOS AIRES)
- Hierros y Aceros Industriales S.A., San Adrian de Besos, Barcelona, Spain. (*Small castings*) (BARCELONA)
- Highveld Steel & Vanadium Corp. Ltd., Witbank, South Africa. (*Sections and flats*) (VEREENIGING)
- Himmat Steel Foundry Private Ltd., P.O. Kumhari, District Durg, M.P. (India). (*Castings*) (JAMSHEDPUR)
- Hindustan Steel Ltd.  
     Bhilai Steel Project, Bhilai, Madhya Pradesh, India. (*Ingots, blooms, billets and sections*) (CALCUTTA)  
     Durgapur Steel Plant, West Bengal, India. (*Blooms, billets, bars and sections*) (CALCUTTA)  
     Rourkela, Orissa, India. (*Ingots, slabs and plates*) (CALCUTTA)
- Hitachi, Ltd.  
     Hitachi Works, Hitachi, Japan. (*Castings*) (YOKOHAMA)  
     Katsuta Works, Katsuta, Japan. (*Ingots, forgings and castings*) (YOKOHAMA)
- Hitachi Metals, Ltd.  
     Tobata Works, Kitakyushu, Japan. (*Castings*) (SHIMONOSEKI)  
     Yasugi Works, Yasugi, Japan. (*Ingots, bars and forgings*) (KOBE)
- Hitachi Shipbuilding & Engineering Co., Ltd.  
     Chikko Shipyard, Osaka, Japan. (*Ingots, castings and forgings*) (OSAKA)
- Hokuriku Kogyo Co. Ltd., Sanjo Plant, Sanjo, Japan. (*Small forgings*) (YOKOHAMA)
- Howa Machinery Ltd., Inazawa Plant, Inazawa, Japan. (*Castings*) (NAGOYA)
- Hubner-Vamag, Vereinigte Armaturenfabriken, Aktiengesellschaft, Vienna, Austria. (*Castings*) (VIENNA)
- Hults Bruk A.B., Aby, Sweden. (*Castings*) (STOCKHOLM)



# APPROVED MANUFACTURERS AND PROVING ESTABLISHMENTS

- Huta 1 Maja, Gliwice, Poland. (*Ingots and forgings*) (KATOWICE)
- Huta Baildon, Katowice, Poland. (*Ingots, forgings and bars*) (KATOWICE)
- Huta Batory, Chorzow-Batory, Poland. (*Forgings, plates and tubes*) (KATOWICE)
- Huta im Bieruta, Czesochowa, Poland. (*Seamless tubes and rolling mill for plates*) (KATOWICE)
- Huta Bobrek, Bytom, Poland. (*Ingots, slabs and blooms*) (KATOWICE)
- Huta im. M. Buczka, Sosnowiec, Poland. (*Seamless tubes*) (KATOWICE)
- Huta Dzierzynski, Dabrowa Gornicza, Poland. (*Billets, sections and bars*) (KATOWICE)
- Huta Florian, Swietochlowice, Poland. (*Angles and bars*) (KATOWICE)
- Huta Jednosc, Siemianowice Slaskie, Poland. (*Ingots and seamless tubes*) (KATOWICE)
- Huta Kosciuszko, Chorzow, Poland. (*Billets, blooms, sections and rivet bars*) (KATOWICE)
- Huta Labedy, Labedy, Poland. (*Flats and sections*) (KATOWICE)
- Huta im. Lenina, Krakow, Poland. (*Ingots, slabs, plates*) (KATOWICE)
- Huta Malapanew, Ozimek k/Opola, Poland. (*Castings*) (KATOWICE)
- Huta Nowotko, Ostrowiec Swietokrzyski, Poland. (*Sections*) (KATOWICE)
- Huta Pokoj, Ruda Slaska, Poland. (*Plates, sections and small forgings*) (KATOWICE)
- Huta Stalowa Wola, Stalowa Wola, Poland. (*Castings, forgings, plates and sections*) (KATOWICE)
- Huta Warszawa, Warsaw, Poland. (*Ingots, forgings and rolled bars*) (KATOWICE)
- Huta Zawiercie, Zawiercie, Poland. (*Flats and bars*) (KATOWICE)
- Hyundai International Inc., Gunpo Plant, Seoul, Korea. (*Castings*) (SEOUL)
- Indian Iron & Steel Co., Ltd.  
Burnpur Works, Burnpur, West Bengal, India. (*Sections and angles*) (CALCUTTA)  
Kulti Iron Works, Kulti, India. (*Castings*) (CALCUTTA)
- Indian Tube Company Ltd., Jamshedpur, India. (*Electric resistance welded tubes and seamless tubes*) (CALCUTTA)
- Industrias del Besos, S.A., Barcelona, Spain. (*Small sections and bars*) (BARCELONA)
- Industrias Mecanicas, Sociedad Anonima, Barcelona, Spain. (*Castings*) (BARCELONA)
- Interprinderea de Constructii de Masini, Resitza, Rumania. (*Castings and forgings*) (GALATZ)
- Interprovincial Steel and Pipe Corporation Ltd., Regina, Saskatchewan, Canada. (*Plates*) (TORONTO)
- Ishikawajima-Harima Heavy Industries Co. Ltd., Aioi Works, Aioi, Japan. (*Castings and forgings*) (KOBE)  
Tokyo Works, Tokyo, Japan. (*Ingots, forgings and castings*) (YOKOHAMA)
- "ITALSIDER" S.p.A., Head Office: Via Corsica 4, Genoa, Italy.  
Centro Siderurgico di Bagnoli, Naples. (*Ingots, sections and bars*) (NAPLES)  
Centro Siderurgico "Oscar Sinigaglia" Campi Works. (*Ingots, forgings, plates and castings*) (GENOA)  
Centro Siderurgico "Oscar Sinigaglia", Oscar Sinigaglia Works, Genoa-Cornigliano. (*Ingots, slabs and plates*) (GENOA)  
Stabilimento di Lovere. (*Sections, bars, castings and forgings*) (MILAN)  
Stabilimento di Marghera. (*Rolling mills for small sections and bars*) (VENICE)  
Stabilimento di Taranto. (*Ingots, slabs and plates*) (NAPLES)
- Izuo Chukosho Co., Ltd., Osaka, Japan. (*Castings*) (OSAKA)
- JMC Engineering Co. Ltd., Takaoka, Japan. (*Castings*) (OSAKA)
- Japan Casting Co. Ltd., Kawasaki, Japan. (*Castings*) (YOKOHAMA)
- Japan Casting and Forging Corporation, Kitakyshu, Japan. (*Forgings and castings*) (SHIMONOSEKI)
- Japan Drop Forge Co., Ltd., Amagasaki, Japan. (*Small forgings*) (KOBE)
- Japan Special Steel Co., Ltd., Tokyo, Japan. (*Ingots, forgings, blooms, billets and bars*) (YOKOHAMA)
- Japan Steel Works Ltd.  
Hiroshima Works, Hiroshima, Japan. (*Forgings and castings*) (HIROSHIMA)  
Muroran Works, Muroran, Japan. (*Ingots, forgings, castings and plates*) (YOKOHAMA)
- Jemappes, Société Anonyme Forges et Laminoirs de, Jemappes, near Mons, Belgium. (*Ingots, blooms and bars*) (ANTWERP)
- Jernstøberiet Kongeaa A/S, Vamdrup, Denmark. (*Castings*) (ODENSE)
- Joban Machinery Co. Ltd., Uchigo Factory, Iwaki, Japan. (*Castings*) (YOKOHAMA)
- Jonan Iron Works Co. Ltd., Haneda Works, Tokyo, Japan. (*Small forgings*) (YOKOHAMA)
- Jones & Laughlin Steel Corporation, Pittsburgh, Pa., U.S.A. (*Plates, sections, bars and tubes*) (CLEVELAND, O.)
- Jorgensen, Earle, M. Co., Forge Division, Seattle, Washington. (*Ingots and forgings*) (SEATTLE)
- K.G.M.-Altalanos Gepipari Igazgatóság, Budapest, Hungary.  
Works: Öntödei Vallalat Kobanyai vas-es Acelontödeje, Budapest. (*Castings*) (VIENNA)
- K.G.M. Jármuipari Igazatóság, Budapest, Hungary.  
Works: Magyar Vagon-és Gépgyár, Györ. (*Castings*) (VIENNA)



# LLOYD'S REGISTER OF SHIPPING

- Takegawa Endo Iron Works Co., Ltd.,** Takegawa, Japan. (*Forgings*) (YOKOHAMA)  
**Kamahara Steel Casting Manufacturing Co. Ltd.,** Kochi, Kochi-ken, Japan. (*Steel castings*) (KOBE)  
**Kanda Sangyo Co., Ltd.,** Kawasaki, Japan. (*Small forgings*) (YOKOHAMA)  
**Kangwon Industrial Co. Ltd.,** Pohang Works, Korea. (*Castings*) (SEOUL)  
**Kansai Steel Corp.,** Sakai, Japan. (*Ingots, bars and sections*) (OSAKA)  
**Kansai Tekko Co., Ltd.,** Amagasaki, Japan. (*Small forgings*) (KOBE)  
**Kanto Special Steel Works, Ltd.,** Fujisawa, Japan. (*Forgings*) (YOKOHAMA)  
**Kawaguchi Metal Industries Co. Ltd.,** Kawaguchi, Japan. (*Castings*) (YOKOHAMA)  
**Kawasaki Heavy Industries Ltd.,** Crushing Plant Mfg. Division, Tokyo, Japan. (*Castings*) (YOKOHAMA)  
**Kawasaki Steel Corporation, Japan.**  
     **Chiba Works, Chiba.** (*Slabs and plates*) (YOKOHAMA)  
     **Chita Works, Handa.** (*Ingots, castings and seamless tubes and pipes*) (NAGOYA)  
     **Fukiai Works, Kobe.** (*Blooms and sections*) (KOBE)  
     **Mizushima Works, Mizushima, Japan.** (*Ingots, forgings, castings, bars, plates and sections*) (KOBE)  
**Kinka Kikai Co. Ltd.,** Gifu, Japan. (*Castings*) (NAGOYA)  
**Kiyomoto Ironworks Co. Ltd.,** Takeo Works, Japan. (*Castings*) (NAGASAKI)  
**Klinger, Rich.,** Aktiengesellschaft, Gumpoldskirchen, near Vienna, Austria. (*Small castings*) (VIENNA)  
**Klöckner-Werke A.G.**  
     **Works: Hütte Bremen, Federal Republic of Germany.** (*Plates*) (BREMEN)  
     **Works: Georgsmarienhütte, Federal Republic of Germany.** (*Ingots and bars*) (HANNOVER)  
     **Works: Mannstaedt-Werke, Troisdorf, Federal Republic of Germany.** (*Rolling mills for sections*) (COLOGNE)  
     **Works: Osnabrück, Federal Republic of Germany.** (*Forgings and castings*) (HANNOVER)  
**Knorr-Bremse G.m.b.H.,** Volmarstein-Schmandbruch, Federal Republic of Germany. (*Castings*) (DORTMUND)  
**Kobe Steel Ltd.**  
     **Amagasaki Works, Japan.** (*Ingots, sections and bars*) (KOBE)  
     **Kakogawa Works, Kakogawa, Japan.** (*Ingots and plates*) (KOBE)  
     **Kobe Works, Japan.** (*Ingots, blooms, billets, bars and castings*) (KOBE)  
     **Takasago Works, Takasago, Japan.** (*Ingots, forgings and castings*) (KOBE)  
**Kobukuro Iron Works Co. Ltd.,** Iizuka Works, Iizuka, Japan. (*Castings*) (SHIMONOSEKI)
- Kockums Jernverk, Kallinge, Sweden.** (*Ingots and castings*) (MALMO)  
**Kohlswa Jernverks Aktiebolag.** (*Ingots, forgings and castings*) (STOCKHOLM)  
**Kokoku Steel Casting Co., Ltd.,** Osaka, Japan. (*Castings*) (OSAKA)  
**Komatsu Ltd.**  
     **Awazu Plant, Komatsu, Japan.** (*Castings*) (OSAKA)  
     **Osaka Plant, Hirakata, Japan.** (*Castings*) (OSAKA)  
**Korea Heavy Machinery Industries Ltd. (KOHEMA),** Seoul, Korea. (*Castings*) (SEOUL)  
**Kotobuki Industries Co., Ltd.,** Hiro Works, Kure, Japan. (*Castings*) (HIROSHIMA)  
**Krauss-Maffei A.G.,** München-Allach, Federal Republic of Germany. (*Castings*) (AUGSBURG)  
**Kruiner Gusstahlwerk, Gevelsberg, Federal Republic of Germany.** (*Castings*) (DORTMUND)  
**Kubota Ltd.,** Hirakata Plant, Hirakata, Japan. (*Castings*) (OSAKA)  
**Kumardhubi Engineering Works Ltd.,** P.O. Box Kumardhubi, Dist. Dhanbad, (Bihar), India. (*Castings*) (CALCUTTA)  
**Kureha Seiko Co. Ltd.,** Osaka, Japan. (*Castings*) (OSAKA)  
**Kurimoto Iron Works Ltd.,** Kagaya Factory, Osaka, Japan. (*Castings*) (OSAKA)  
**Latrobe Forge & Spring, Inc.** Latrobe, Pa., U.S.A. (*Ingots and forgings*) (CLEVELAND, O.)  
**Lebanon Steel Foundry, Lebanon, Pa., U.S.A.** (*Castings*) (PHILADELPHIA)  
**Leonard-Giot, Société Anonyme Usines & Aciéries, Marchienne-au-Pont, Belgium.** (*Castings*) (ANTWERP)  
**Lesjöfors AB, Lesjöfors, Sweden.** (*Ingots and billets*) (KRISTINEHAMN)  
**Letson & Burpee, Ltd.,** Surrey, British Columbia, Canada. (*Small castings*) (VANCOUVER)  
**Llodio, S.A.,** Aceros de Llodio, near Bilbao, Spain. (*Castings, ingots, forgings and rolled bars*) (BILBAO)  
**Luigi Giudici, Società per Asioni, Rescaldina, Milan, Italy.** (*Small castings*) (MILAN)  
**Lukens Steel Company, Coatesville, Pa., U.S.A.** (*Plates*) (PHILADELPHIA)  
**Luzuriaga, Victorio, S.A.,** Pasajes, Guipuzcoa, Spain. **Works: Usurbil, Guipuzcoa.** (*Castings*) (BILBAO)  
**Lynn Macleod Metallurgy Ltd.,** Thetford Mines, P.Q., Canada. (*Castings*) (MONTREAL)  
**Maekawa Electric Steel Castings Co.**  
     **Osaka, Japan.** (*Castings*) (OSAKA)  
     **Tobata Factory, Kitakyushu, Japan.** (*Castings*) (SHIMONOSEKI)  
**Magyar Vas-és Acélpári Egyesülés, Budapest, Hungary.**  
     **Works: Dunai Vasmű, Dunaujváros.** (*Ingots, slabs and plates*) (VIENNA)  
     **Works: Dunai Vasmű, Lörinci Hengerműve, Budapest.** (*Rolling mill for plates*) (VIENNA)



# APPROVED MANUFACTURERS AND PROVING ESTABLISHMENTS

Magyar Vas-és Acélpári Egyesülés—*continued*

*Works:* Lenin Kohászati Művek, Miskolc-Diósgyőr.  
(*Ingots, slabs, sections, bars, castings and forgings*)  
(VIENNA)

*Works:* Ozdi Kohászati üzemek, Ozd. (*Ingots, slabs, plates, sections and bars*) (VIENNA)

Mahindra Ugin Steel Co., Ltd., Khapoli Works, Bombay, India. (*Bars, billets and sections*) (BOMBAY)

Mainland Foundry & Eng. Ltd., Vancouver, B.C., Canada. (*Castings*) (VANCOUVER)

Makine ve Kimya Endustri, Celik Fabrikasi, Kirikkale, Turkey. (*Ingots, forgings, rolled sections and bars*) (ISTANBUL)

Manitoba Rolling Mills Division of Dominion Bridge Co., Ltd., Selkirk, Manitoba, Canada. (*Billets, bars and sections*) (MONTREAL)

Mannesmann A.G. Huttenwerke, Duisburg-Huckingen, Federal Republic of Germany. (*Ingots, slabs and bars*) (DUSSELDORF)

Mannesmannrohren-Werke G.m.b.H., Dusseldorf, Federal Republic of Germany. (*Seamless and welded tubes*) (DUSSELDORF)

Manoir-Pompey, Acieries du, 27 Pitres, France. (*Castings*) (ROUEN)

Maritime Steel and Foundries, Ltd., New Glasgow, Nova Scotia. (*Small castings*) (HALIFAX, N.S.)

Marrel Frères, Société Anonyme des Etablissements, Usine des Etaings, near Rive-de-Gier 42, France. (*Ingots, plates and bars*) (LYONS)

Masini Grele, Usina de, Bucharest, Rumania. (*Forgings*) (GALATZ)

Mason & Cox, Pty. Ltd., Adelaide, S. Australia. (*Castings*) (ADELAIDE)

Material y Construcciones S.A., Barcelona, Spain. (*Castings*) (BARCELONA)

Maubeuge, Société Anonyme de la Fabrique de Fer de, Louvroil (Nord), France. (*Ingots*) (VALENCIENNES)

Maximilianshütte, Eisenwerk-Gesellschaft m.b.H., Sulzbach-Rosenberg, Bavaria, Federal Republic of Germany. Haidhof Works: (*Ingots, billets, bars, small sections and thin plates*) (AUGSBURG)

Metal & Steel Factory, Ishapore, West Bengal, India. (*Ingots, blooms, billets, forgings, castings and bars*) (CALCUTTA)

Metallurgique et Minière de Rodange-Athus S.A., Rodange, Luxembourg. (*Sections*) (NANCY)

Metalurgica Duarte Ferreira S.A.R.L., Tramagal, Portugal. (*Castings*) (LISBON)

Metalurgica Madrilenia S.A., Alcala de Henares, Madrid, Spain. (*Castings*) (MADRID)

Metalurgica del Nalon S.A. (MENASA), Lada, Spain. (*Castings*) (GIJON)

Meuse, Société Métallurgique de la, Forges et Acieries de Stenay 55, Stenay, France. (*Castings*) (NANCY)

Midvale-Heppenstall Company, Nicetown, Philadelphia, Pa., U.S.A. (*Forgings*) (PHILADELPHIA)

Mitsubishi Heavy Industries Ltd.

Hiroshima Shipyard & Engine Works, Hiroshima, Japan. (*Ingots, castings and small forgings*) (HIROSHIMA)

Kobe Shipyard & Engine Works, Kobe, Japan. (*Ingots, small forgings and castings*) (KOBE)

Mihara Machinery Works, Mihara, Japan. (*Castings and forgings*) (HIROSHIMA)

Nagasaki Shipyard & Engine Works, Nagasaki, Japan. (*Castings*) (NAGASAKI)

Takasago Machinery Works, Takasago, Japan. (*Forgings*) (KOBE)

Yokohama Shipyard and Engine Works, Yokohama, Japan. (*Castings*) (YOKOHAMA)

Mitsubishi Metal Corporation, Okegawa Plant, Okegawa, Japan. (*Small castings*) (YOKOHAMA)

Mitsubishi Steel Manufacturing Co. Ltd.

Hirota Works, Fukushima Pref., Japan. (*Ingots and castings*) (YOKOHAMA)

Tokyo Works, Tokyo, Japan. (*Billets, bars and small forgings*) (YOKOHAMA)

Utsunomiya Works, Utsunomiya, Japan. (*Ingots*) (YOKOHAMA)

Mitsui Miike Machinery Co., Ltd., Miike Works, Omuta, Japan. (*Castings*) (NAGASAKI)

Mitsui Shipbuilding & Engineering Co., Ltd., Japan.

Fujinagata Works, Osaka, Japan. (*Forgings*) (OSAKA)

Tamano Works, Tamano, Japan. (*Ingots, forgings and castings*) (KOBE)

Mitsumoto Valve Manufacturing Co. Ltd., Fujiidera, Japan. (*Small forgings and small castings*) (OSAKA)

Miyazaki Iron Works Co., Ltd., Osaka, Japan. (*Small forgings*) (OSAKA)

Motala Verkstad, A/B, Motala Verkstad, Sweden. (*Ingots and castings*) (GOTHENBURG)

Mukand Iron & Steel Works, Ltd., Kurla, Bombay, 70, India. (*Castings*) (BOMBAY)

Mysore, The, Iron & Steel Works Ltd., Bhadravati, India. (*Bars, billets, blooms and sections*) (MADRAS)

Nagasaki Metal Industries Association, Isahaya, Japan. (*Small forgings*) (NAGASAKI)

Nakayama Steel Products Co. Ltd., Tsurumi Works, Yokohama, Japan. (*Ingots and plates*) (YOKOHAMA)

Nakayama Steel Works Ltd., Japan.

Funamachi Works, Osaka. (*Ingots and plates*) (OSAKA)

Nagoya Works, Aichi Prefecture. (*Slabs*) (NAGOYA)

National Forge Co.

Erie Division, Erie, Pennsylvania, U.S.A. (*Ingots, forgings and castings*) (CLEVELAND, O.)

Irvine, Warren County, Pennsylvania, U.S.A. (*Ingots and forgings*) (CLEVELAND, O.)

National Iron & Steel Co., Ltd., Stephen House, Calcutta, 1, India. (*Castings*) (CALCUTTA)



# LLOYD'S REGISTER OF SHIPPING

- National Iron & Steel Mills Ltd., Jalan Besi Baja, Jurong Industrial Estate, Singapore. (*Small sections and bars*) (SINGAPORE)
- Nazionale "Cogne", S.p.A. Head Office: Turin. Works: Aosta. (*Ingots, blooms, billets and bars*) (GENOA)
- Neunkircher Eisenwerk A.G., Neunkirchen/Saar, Federal Republic of Germany.  
Homburg Works. (*Ingots and seamless tubes*) (SAARBRÜCKEN)  
Neunkirchen Works. (*Ingots, bars and sections*) (SAARBRÜCKEN)
- Newport News Shipbuilding & Dry Dock Co., Newport News, Va., U.S.A. (*Castings and forgings*) (NEWPORT NEWS)
- Niederrheinstahl G.m.b.H., Stahl-und Rohrenwerke, Dinslaken, Federal Republic of Germany. (*Ingots, billets for tubes and bars*) (DUSSELDORF)
- Nippon Kokan Kabushiki Kaisha.  
Fukuyama Iron Works, Fukuyama, Japan. (*Ingots, blooms, sections and plates*) (KOBE)  
Keihin Iron Works, Kawasaki, Japan. (*Ingots, plates, tubes, bars and sections*) (YOKOHAMA)  
Tsurumi Shipyard, Yokohama, Japan. (*Small forgings*) (YOKOHAMA)
- Nippon Satetsu Steel Co. Ltd., Shikama Works, Himeji, Japan. (*Ingots, bars and sections*) (KOBE)
- Nippon Sharyo Seizo Kaisha, Ltd., Nagoya, Japan. (*Castings*) (NAGOYA)
- Nippon Stainless Steel Co., Ltd., Naoetsu Works, Joetsu, Japan. (*Ingots, forgings, castings and plates*) (YOKOHAMA)
- Nippon Steel Corporation.  
Hirohata Works, Hirohata, Japan. (*Ingots, billets, plates and sections*) (KOBE)  
Kamaishi Works, Kamaishi, Japan. (*Sections and bars*) (YOKOHAMA)  
Kimitsu Works, Kimitsu, Japan. (*Ingots, sections, plates and electric resistance welded tubes*) (YOKOHAMA)  
Muroan Works, Muroan, Japan. (*Billets, sections and bars*) (YOKOHAMA)  
Nagoya Works, Tokai, Japan. (*Ingots, plates and electric resistance welded tubes*) (NAGOYA)  
Oita Works, Oita, Japan. (*Plates*) (NAGASAKI)  
Plant and Machinery Division, Kitakyushu, Japan. (*Castings and forgings*) (SHIMONOSEKI)  
Sakai Works, Sakai, Japan. (*Ingots, sections and thin plates*) (OSAKA)  
Tokyo Works, Tokyo, Japan. (*Rolling mills for seamless, rolled or drawn tubes*) (YOKOHAMA)  
Yawata Works, Kitakyushu, Japan. (*Plates, sections and ingots*) (SHIMONOSEKI)
- Nippon Steel Foundry Co., Ltd., Osaka, Japan. (*Castings*) (OSAKA)
- Nippon Yakin Kogyo Co., Ltd.,  
Kanazawa Works, Kanazawa, Japan. (*Castings in special steels*) (OSAKA)  
Kawasaki Works, Kawasaki, Japan. (*Ingots, forgings, bars and thin plates*) (YOKOHAMA)
- Nishinihon Tanko Co. Ltd., Fukuoka Prefecture, Japan. (*Small forgings*) (SHIMONOSEKI)
- Nishiyodo Steel Making Co. Ltd., Osaka, Japan. (*Castings*) (OSAKA)
- Nisshin Steel Co. Ltd., Kure Works, Kure, Japan. (*Ingots, blooms, billets and strip*) (HIROSHIMA)
- Nittoku Metal Industry Co., Ltd., Tokyo, Japan. (*Small forgings*) (YOKOHAMA)
- Nordische Stahlwerke, Bach & Co., Neümunster, Federal Republic of Germany. (*Castings*) (KIEL)
- Norrbottens Järnverk Aktiebolag, Lulea, Sweden. (*Ingots, slabs, blooms, billets, bars and sections*) (STOCKHOLM)
- Norsk Jernverk, A/S., Mo-i-Rana, Norway. (*Electric steel ingots, billets, sections and bars*) (OSLO)
- Nová huť Klementa Gottwalda, národní podnik (New Metallurgical Works of Klement Gottwald, National Corporation), Ostrava-Kunčice, Czechoslovakia. (*Ingots*) (VIENNA)
- Nueva Montana Quijano S.A., Nueva Montana, Santander, Spain. (*Castings*) (BILBAO)
- Oji Steel Co. Ltd., Gunma Plant, Gunma Pref., Japan. (*Ingots, billets and flat bars*) (YOKOHAMA)
- Okamoto Iron Works Co., Kobe, Japan. (*Forgings*) (KOBE)
- Okano Valve Manufacturing Co., Yukuhashi Foundry, Yukuhashi, Japan. (*Small castings and small forgings*) (SHIMONOSEKI)
- Olarra S.A., Larrondo, Lujúa, Vizcaya, Spain. (*Ingots and rolled bars*) (BILBAO)
- Onomichi Anchor Manufacturing Co. Ltd., Fukuyama, Japan. (*Castings*) (KOBE)
- Oranje Nassau Staal B.V., Heerlen, Holland. (*Small castings*) (ROTTERDAM)
- Oregon Steel Mills, Division of Gilmore Steel Corp., 5200 N.W. Front Ave., Portland, Oregon 97210, U.S.A. (*Rolling mill for plates and sections*) (SEATTLE)
- Orion S.p.A., Porto Industriale, Trieste, Italy. (*Forgings and castings*) (TRIESTE)
- Osaka Chain & Machinery Co. Ltd., Kaizuka Works, Kaizuka, Japan. (*Small castings*) (OSAKA)
- Osaka Steel Casting Co., Ltd., Osaka, Japan. (*Small castings*) (OSAKA)
- Osaka Steel Tube Co., Ltd., Sasebo Works, Sasebo, Japan. (*Seamless tubes*) (SASEBO)
- Ovako Oy, Äminnefors Steel Works, Äminnefors, Finland. (*Ingots, billets, bars and sections*) (TURKU/ÅBO)
- Ovako Oy, Imatra Steel Works, Imatra, Finland. (*Ingots, slabs, blooms, billets, bars, sections and castings*) (HELSINKI/HELSINGFORS)
- Oy Fiskars Ab Salon Konepaja Salo, Finland. (*Small castings*) (ÅBO)
- Oy Koverhar Ab, Lappvik, Finland. (*Billets*) (ÅBO)
- Oy W. Rosenlew, A/B, Porin Konepaja, Pori, Åbo, Finland. (*Small castings*) (TURKU/ÅBO)



# APPROVED MANUFACTURERS AND PROVING ESTABLISHMENTS

Oy Stenberg, John, Ab, Helsinki, Finland. (*Small castings*) (HELSINKI/HELSINGFORS)

Oy Wartsila A/B, Steel Mill, Dalsbruk, Finland. (*Ingots, billets, bars and castings*) (HELSINKI/HELSINGFORS)

Ozuki Seikoshō, Ltd., Shimonoseki, Japan. (*Castings*) (SHIMONOSEKI)

Pacific Metals Ltd.

Naoetsu Factory, Naoetsu, Japan. (*Ingots and castings*) (YOKOHAMA)

Toyama Factory, Toyama, Japan. (*Ingots and forgings*) (OSAKA)

Pacific States Steel Corporation, Union City, Cal., U.S.A. (*Ingots, sections and bars*) (SAN FRANCISCO)

Pacific Steel Castings Co., Berkeley, Cal., U.S.A. (*Castings*) (SAN FRANCISCO)

Pacifico, Compañia de Acero del, S.A., Talcahuano, Chile. (*Ingots, plates, bars and sections*) (VALPARAISO)

Paderwerk Gebr. Benteler, Schlossneuhau, Federal Republic of Germany. (*Seamless tubes*) (DORTMUND)

Paris et d'Outreau, Acieries de, Société Anonyme, Usines d'Hirson, Hirson, Aisne, France. (*Castings*) (VALENCIENNES)

Usine d'Outreau, Pas de Calais, France. (*Castings*) (DUNKIRK)

Paris-Seine, Fonderies et Acieries de, Usine de la Folie, Avenue de Bobigny, Noisy le Sec (Seine), France. (*Castings*) (PARIS)

Pennsylvania Steel Foundry and Machine Company, Hamburg, Pa., U.S.A. (*Castings*) (PHILADELPHIA)

Phoenix Steel Corporation.

Works: Claymont, Delaware, U.S.A. (*Plates*) (PHILADELPHIA)

Works: Structural Division, Phoenixville, Pa., U.S.A. (*Sections, bars and rotary forged seamless tubes*) (PHILADELPHIA)

Pinetown Engineering Foundry Co. (Pty.) Ltd., Pinetown, Natal, South Africa. (*Castings*) (DURBAN)

Pohang Iron and Steel Co., Ltd., Pohang Works, Pohang, Korea. (*Rolling mill for plates*) (BUSAN)

Pohlig-Heckel-Bleichert, Vereinigte Maschinenfabriken A.G., Abt. Stahlformgiesserei, Werk Heckel, Rohrbach/Saar, Federal Republic of Germany. (*Castings*) (SAARBRÜCKEN)

Pont à Mousson, S.A., Usine de Fumel, France. (*Castings, centrifugal cast pipes*) (MARSEILLES)

Porter, H. K. (France) Acieries Division Marpent, Marpent (Nord), France. (*Ingots for forging, castings*) (VALENCIENNES)

Pusan Pokum Ind. Co. Ltd., Busan, Korea. (*Castings*) (BUSAN)

Quaker Alloy Casting Co., Myerstown, Pa., U.S.A. (*Castings*) (PHILADELPHIA)

Raahe Oy, Raahe, Finland. (*Small castings*) (HELSINKI/HELSINGFORS)

Rasa Industries Ltd., Hainuzuka Works, Chikugo, Japan. (*Castings*) (SHIMONOSEKI)

Rauma Repola Oy, Lokomon Tehtaat, Tampere, Finland. (*Ingots, forgings and castings*) (HELSINKI/HELSINGFORS)

Rautaruukki Oy, Raahe, Finland. (*Ingots and plates*) (HELSINKI/HELSINGFORS)

Republic Steel Corporation, Cleveland, O., U.S.A.

Chicago Plant, Chicago, Ill., U.S.A.

Works: 118th Street, Chicago. (*Rolling mills*)

East Chicago, Ind. (*Bars*) (CHICAGO)

Southern District, Gadsden, Alabama, U.S.A. (*Plates*) (MOBILE)

Rhein Stahl Giesserei A.G.,

Gussstahlwerk Gelsenkirchen, Federal Republic of Germany. (*Castings*) (DUSSELDORF)

Gussstahlwerk Oberkassel, Dusseldorf-Oberkassel, Federal Republic of Germany. (*Ingots and castings*) (DUSSELDORF)

Friedrich Wilhelms-Hütte, Mulheim/Ruhr, Federal Republic of Germany. (*Castings*) (DUSSELDORF)

Riken Tanzo Co., Ltd., Maebashi Plant, Maebashi, Japan. (*Small forgings*) (YOKOHAMA)

Rikimi Cast Steel Co. Ltd., Higashi, Osaka, Japan. (*Small castings*) (OSAKA)

Rohrenwerke Bous G.m.b.H., Bous/Saar, Federal Republic of Germany. (*Seamless tubes*) (SAARBRÜCKEN)

Rotterdamsche Droogdok Maatschappij, Rotterdam, Holland. (*Ingots, forgings and small castings*) (ROTTERDAM)

Rudarsko - Metalurski Kombinat - Zenica, Zeljezara Zenica, Zenica, Yugoslavia. (*Billets, bars, sections and forgings*) (SPLIT)

Rudnici I Zelezara Smederevo, Smederevo, Yugoslavia. (*Small castings*) (SPLIT)

Rudnici I Zelezarnica, "Skopje", Skopje, Yugoslavia. (*Plates*) (SPLIT)

Saab-Scania, Nordarmaturdivisionen, Linköping, Sweden. (*Castings*) (STOCKHOLM)

S.A.F.A.S.—Societa Azionaria Fonderia Acciai Speciali, Tavernelle di Altavilla Vicentina (Vicenza), Italy. (*Castings*) (VENICE)

S.A.F.A.U. Ferriere Acciaierie di Udine, Udine, Italy. (*Ingots, forgings, blooms, bars and sections*) (TRIESTE)

SACILOR, France.

Etablissement d'Hagondange, 57 Hagondange. (*Blooms, billets, bars and sections*) (NANCY)

Etablissement d'Orne-Amont, 54 Homecourt. (*Ingots, blooms, billets, narrow plates and universal flats*) (NANCY)

Usine de Gandrange, 57 Gandrange. (*Ingots, blooms, billets and flat bars*) (NANCY)

Usine de Knutange, 57 Hayange. (*Sections*) (NANCY)

Usine de Rombas, 57 Rombas. (*Ingots, blooms, billets, bars and sections*) (NANCY)

Usine de St. Jacques, 57 Hayange. (*Rolling mill for sections*) (NANCY)



# LLOYD'S REGISTER OF SHIPPING

- Safog, S.A., Fonderie Officine di Gorizia, Gorizia, Italy. (*Castings*) (TRIESTE)
- Sambre et Meuse, Société Anonyme des Usines et Acieries de.  
Usines de Feignies, Feignies (Nord), France. (*Castings*) (VALENCIENNES)  
Usines de Saint Briec (Côtes-du-Nord), France. (*Small castings*) (NANTES)
- Sande Giesserei, Sande-Oldenburg, Federal Republic of Germany. (*Castings*) (BREMEN)
- Sandusky Foundry & Machine Co., Sandusky, Ohio, U.S.A. (*Castings*) (CLEVELAND)
- Sandvik Aktiebolag, Sandviken, Sweden. (*Ingots, forgings and tubes*) (STOCKHOLM)
- Sanyo Special Steel Co., Ltd., Himeji, Japan. (*Ingots, forgings and rolled bars*) (KOBE)
- Sasebo Heavy Industries Co. Ltd., Sasebo Shipyard, Sasebo, Japan. (*Forgings*) (SASEBO)
- Sasebo Seiko Co. Ltd., Shiratake-cho, Sasebo, Japan. (*Ingots and castings*) (SASEBO)
- Saut-du-Tarn, Société Nouvelle Du, 81-Saint-Juery, France. (*Castings*) (MARSEILLES)
- Scaw Metals, Ltd., Union Junction, Transvaal, S. Africa. (*Rivet bars, small rolled sections and castings*) (VEREENIGING)
- Schmidt & Clemens, Edelstahlwerk, Kaiserau b/Engelskirchen, Bez. Köln, Federal Republic of Germany. (*Ingots, forgings, castings and bars*) (COLOGNE)
- Schoeller-Bleckmann Stahlwerke A.G., Vienna.  
*Works*: Muerzzuschlag-Hoenigsberg, Styria. (*Bars*) (VIENNA)  
*Works*: Ternitz, Low Austria. (*Castings, forgings and bars*) (VIENNA)
- Schutte, Meyer & Co., G.m.b.H., Letmathe, Westphalia, Federal Republic of Germany. (*Small castings*) (DORTMUND)
- Seibu Kogyo Co., Ltd., Yawata Steel Casting Works, Kitakyushu, Japan. (*Castings*) (SHIMONOSEKI)
- Seo Koatsu Kogyo Co., Ltd., Osaka, Japan. (*Small forgings*) (OSAKA)
- Sharon Steel Corporation, Roemer Works, Farrell, Pa., U.S.A. (*Ingots, blooms and billets*) (CLEVELAND)
- Shimizu Kotetsu Co., Ltd., Tokyo, Japan. (*Forgings*) (YOKOHAMA)
- Shin Nippon Drop Forging Co. Ltd., Kawasaki, Japan. (*Small forgings*) (YOKOHAMA)
- Showa Steel Tube Works Ltd., Sakai, Japan. (*Seamless tubes*) (OSAKA)
- Siderurgia Nacional, S.a.r.l., Seixal, Portugal. (*Sections and bars*) (LISBON)
- Siderurgica Ebroacero S.A., Zaragoza, Spain. (*Castings*) (BILBAO)
- SIDMAR, Maritieme Staalnijverheid, Gent, Belgium. (*Plates*) (ANTWERP)
- S.I.F.E.M.A. S.A., Bilbao, Spain. (*Steel castings*) (BILBAO)
- S.I.S.M.A. — Società Industrie Siderurgiche Meccaniche & Affini, Villadossola (Novara), Italy. (*Rolled bars and rivets*) (MILAN)
- S.I.T.-S.p.A., Stampaggio Industriale Terni, Terni, Italy. (*Small forgings*) (NAPLES)
- SKF. Stål Hofors Bruk, Hofors, Sweden. (*Billets, bars and forgings, and thick walled tubes*) (STOCKHOLM)
- Škoda, národní podnik, (Skoda National Corporation), České Budějovice Works, Czechoslovakia. (*Castings*) (VIENNA)  
Plzeň Works, Czechoslovakia. (*Castings and forgings*) (VIENNA)
- Slatina narodni podnik, (Slatina National Corporation), Brno, Czechoslovakia. (*Castings*) (VIENNA)
- Smedjebackens Valsverks Aktiebolag, Smedjebacken, Sweden. (*Bars, sections and ingots for re-rolling*) (STOCKHOLM)
- Société des Aciers Fins de l'Est, 57 Hagondange, France. (*Ingots, blooms, billets, bars, plates and sheets*) (NANCY)
- Société Lorraine de Laminage Continu, Sollac, B.P.11, 57 Florange, France. (*Ingots, slabs and plates*) (NANCY)
- Société Métallurgique de Normandie, Mondeville, France. (*Ingots, blooms, billets and bars*) (ROUEN)
- Société Nouvelle des Acieries de Pompey. (*Ingots, blooms, billets, plates, angles and round bars*) (NANCY)
- Sollinger Hütte G.m.b.H., Uslar/Solling, Federal Republic of Germany. (*Castings*) (HANNOVER)
- SOLMER, Fos-sur-Mer, Marseilles, France. (*Plates*) (MARSEILLES)
- Sorel Industries, Ltd., Sorel, P.Q., Canada. (*Ingots and forgings*) (MONTREAL)
- South African Iron & Steel Industrial Corporation, Ltd., "Isacor" Works, Pretoria, Transvaal, S. Africa. (*Ingots, billets, bars, sections and forgings*) (VEREENIGING)
- "Isacor" Works, Vanderbijlpark, Transvaal, S. Africa. (*Ingots, billets, slabs and plates*) (VEREENIGING)
- Staalgieterwerk SMDK, N.V. Utrecht. (*Ingots and castings*) (AMSTERDAM)
- Stahl-u. Röhrenwerke Reisholz G.m.b.H., Federal Republic of Germany. Works at Reisholz. (*Ingots and seamless tubes*) (DUSSELDORF)
- Stahlwerke Bochum A.G., Bochum, Federal Republic of Germany. (*Castings, rolled materials and plates*) (DUSSELDORF)
- Stahlwerk Peine-Salzgitter A.G.,  
Werk Giesserei Heerte, Federal Republic of Germany. (*Castings*) (HANNOVER)  
Werke Peine, Federal Republic of Germany. (*Ingots, billets, sections and bars*) (HANNOVER)  
Werk Salzgitter, Salzgitter-Drutte, Federal Republic of Germany. (*Ingots, plates, bars and sections*) (HANNOVER)



# APPROVED MANUFACTURERS AND PROVING ESTABLISHMENTS

Stahlwerke Rohling-Burbach G.m.b.H., Federal Republic of Germany.

Works: Burbach. (*Ingots, billets, and sections*) (SAARBRUCKEN)

Works: Völkungen. (*Castings, ingots, billets, bars and forgings*) (SAARBRUCKEN)

Stahlwerk Südwestfalen, A.G.

Werk Geisweid, Geisweid Kreis Siegen, Federal Republic of Germany. (*Ingots, bars, billets, thin plates, sheets and coils*) (DORTMUND)

Werksguppe Geisweid, Works Niederschelden, Federal Republic of Germany. (*Ingots and slabs*) (DORTMUND)

Werksguppe Hagen, Werk Wehringhausen, Hagen, Federal Republic of Germany. (*Ingots, bars and forgings*) (DORTMUND)

Standard Steel Division of Titanium Metal Corp. of America, Burnham, Pa., U.S.A. (*Forgings*) (PHILADELPHIA)

Stavanger Staal A.S., Jørpeland, near Stavanger, Norway. (*Castings*) (BERGEN)

Steel Company of Australia, Pty. Ltd., Coburg, Melbourne, Australia. (*Castings*) (MELBOURNE)

Steel Company of Canada, Hamilton, Ontario, Canada. Works: Hamilton. (*Bars, angles, plates and billets*) (TORONTO)

Works: Montreal. (*Bars, angles, plates and billets*) (MONTREAL)

Steirische Gusstahlwerke, A.G., Vienna. Works: Judenburg, Styria, Austria. (*Forgings and bars*) (VIENNA)

Stora Kopparbergs Bergslags A/B, Specialstalverken, Vikmanshyttan, Sweden. (*Forgings, bars and sections*) (STOCKHOLM)

Stora Kopparbergs Bergslags Aktiebolag, Falun, Sweden. Works: Domnarfvet. (*Ingots, sections and plates*) (STOCKHOLM)

Works: Söderfors. (*Forgings, bars and sections*) (STOCKHOLM)

Stramezzi, P., & C., Acciaieria e Ferriera di Crema, Crema, Italy. (*Ingots, bars, small sections and rivets*) (MILAN)

Streicher, M., Asperg/Württ, near Stuttgart, Federal Republic of Germany. (*Castings*) (STUTTGART)

Strømmen Staal A/S, Norway.

Works: Raufoss. (*Castings*) (OSLO)

Strommen. (*Castings*) (OSLO)

Sucesora de Aceros Electricos S.A., Barcelona, Spain. (*Castings*) (BARCELONA)

Sulzer Bros. Ltd., Winterthur, Switzerland. (*Castings and forgings*) (WINTERTHUR)

Sumikin Stainless Steel Tube Co. Ltd., Koga Works, Koga, Japan. (*Fusion welded tubes*) (YOKOHAMA)

Sumitomo Electric Industries, Ltd., Itami Works, Itami, Japan. (*Ingots and small bars*) (KOBE)

Sumitomo Heavy Industries Ltd.,

Ehime Works, Niihama, Japan. (*Castings and forgings*) (KOBE)

Tamashima Works, Kurashiki, Japan. (*Castings*) (KOBE)

Sumitomo Metal Industries, Ltd.

Kashima Steel Works, Kashima, Japan. (*Plates*) (YOKOHAMA)

Kokura Steel Works, Kitakyushu, Japan. (*Ingots, billets, bars and sections*) (SHIMONOSEKI)

Osaka Steel Works, Osaka, Japan. (*Castings, forgings and bars*) (OSAKA)

Steel Tube Works, Amagasaki, Japan. (*Ingots, forgings, small bars, sections and seamless tubes*) (KOBE)

Steel Tube Works, Amagasaki Kainan Plant, Kainan, Japan. (*Seamless tubes*) (OSAKA)

Wakayama Steel Works, Wakayama, Japan. (*Ingots, plates, seamless tubes and electric resistance welded tubes*) (OSAKA)

Sunnan Iron Works Co., Ltd., Yaizu, Japan. (*Forgings*) (YOKOHAMA)

Surahammars Bruks Aktiebolag, Surahammar, Sweden. (*Plates, forgings and castings*) (STOCKHOLM)

Svedala-Arbra Aktiebolag, Svedala, Sweden. (*Castings*) (MALMO)

Svenska Kullagerfabriken, A/B.

Works: Hällefors Jernverk, Hällefors, Sweden. (*Ingots and bars*) (GOTHENBURG)

Works: Katrineholm, Sweden. (*Castings*) (STOCKHOLM)

Svermové Železiarné, Narodny Podnik (Sverma's Iron Works, National Corporation), Podbrezová, Czechoslovakia. (*Ingots and plates*) (VIENNA)

Sydney Steel Corporation, Sydney, N.S., Canada. (*Ingots, billets and sections*) (HALIFAX, N.S.)

Tacca S.p.A., Acciaierie Fonderie, Gallarate, Italy. (*Small castings*) (MILAN)

Tagajo Steel Castings Co. Ltd., Tagajo, Japan. (*Castings*) (YOKOHAMA)

Taiyo Steel Industries Ltd., Isohara Steel Works, Kita-Ibaragi, Japan. (*Castings*) (YOKOHAMA)

Takada Steel Works, Ltd., Yamato-Takada, Japan. (*Castings*) (OSAKA)

Takasaki Metal Industry Co., Ltd., Takasaki Plant, Takasaki, Japan. (*Small castings*) (YOKOHAMA)

Talleres de Deusto S.A., Luchana, Bilbao, Spain. (*Ingots, castings and small forgings*) (BILBAO)

Talleres de Moreda, S.A., Gijon. (GIJON) (*Forgings*)

Tamaris, Société des Ateliers et Fonderies de, Tamaris (Gard), France. (*Castings*) (MARSEILLES)

Tang Eng Iron Works Co., Ltd., Chung Hsin Alloy Steel Plant, Kaohsiung, Taiwan. (*Forgings*) (TAIPEI)

Tata Engineering & Locomotive Co., Ltd., Jamshedpur 4, India. (*Castings*) (CALCUTTA)



- Tata Iron & Steel Co., Ltd., Jamshedpur, India.  
(*Blooms, billets, bars, plates and sections*) (CALCUTTA)
- Teikoku Kokan Seizosho Co. Ltd., Osaka, Japan. (*Seamless tubes*) (OSAKA)
- Teikoku Steel Casting Co., Ltd., Osaka, Japan. (*Castings*) (OSAKA)
- Ten Cate, Heerenveen, Holland. (*Small castings*) (HAREN-GRONINGEN)
- "Terni" Società per l'Industria e l'Elettricità. Works:  
Terni, Italy. (*Ingots, forgings, castings and plates*) (NAPLES)
- Thyssen Henrichshutte, Hattingen Ruhr, Federal Republic of Germany. (*Ingots, plates, forgings and castings*) (DORTMUND)
- Thyssen Niederrhein A.G.,  
Hutten-und Walzwerke, Werk Duisburg, Federal Republic of Germany. (*Rolling mill for narrow flats and sections*) (DUSSELDORF)
- Hutten-und Walzwerke, Oberhausen, Federal Republic of Germany. (*Ingots, plates, sections and bars*) (DUSSELDORF)
- Titovi Zavodi Litostroj, Ljubljana, Yugoslavia. (*Castings*) (RIJEKA)
- Tohoku Special Steel Works Ltd., Sendai, Japan. (*Ingots, small forgings, billets and bars*) (YOKOHAMA)
- Tokai Special Steel Co. Ltd., Tokai, Japan. (*Ingots*) (NAGOYA)
- Tokushu Seiko (Special Steel Mfg.) Co., Ltd., Kawasaki Plant, Kawasaki, Japan. (*Ingots, forgings and bars*) (YOKOHAMA)
- Tokushu Seikoshu Co. Ltd., Kochi, Japan. (*Castings*) (KOBE)
- Tokyo Chain & Anchor Co., Ltd., Naka-Nippon Factory, Aichi Prefecture, Japan. (*Castings*) (YOKOHAMA)
- Tokyo Drop Forging Co. Ltd., Kawasaki Factory, Kawasaki, Japan. (*Small forgings*) (YOKOHAMA)
- Tokyo Precision Forging Works Co., Ltd. (Tokyo Seitan Works Co. Ltd.), Ichikawa, Japan. (*Small forgings*) (YOKOHAMA)
- Topy Industries Ltd., Toyohashi Works, Toyohashi, Japan. (*Ingots, sections and flat bars*) (NAGOYA)
- Torras, Herreria y Construcciones S.A., Calle Pamplona 43, Barcelona, Spain. (*Small sections*) (BARCELONA)
- Toshin Steel Co., Ltd.  
Himeji Works, Himeji, Japan. (*Rolled sections and bars*) (KOBE)
- Tokyo Steel Works, Tokyo, Japan. (*Sections and ingots for forging and plates*) (YOKOHAMA)
- Tosi, Franco, Società per Azioni, Legnano, Italy. (*Forgings and castings*) (MILAN)
- Toyo Kikai-Kinzoku Co. Ltd., Tsuchiyama Plant, Akashi, Japan. (*Small castings and small forgings*) (KOBE)
- Trinecké železářny velké Rijnové socialistické revoluce, národní podnik (Trinec Iron Works Great-Socialistic October Revolution National Corporation), Trinec, Czechoslovakia. (*Ingots, sections, bars and castings*) (VIENNA)
- Trubia, Fábrica Nacional de, Trubia Asturias, Spain. (*Castings and forgings*) (GIJON)
- Tsurumi Steel Tube Co., Ltd., Yokohama, Japan. (*Seamless and welded tubes*) (YOKOHAMA)
- Tube Turns, Philadelphia Plant, Division of Chemetron Corporation, Tacony, Philadelphia, Pa., U.S.A. (*Forgings*) (PHILADELPHIA)
- Türkiye Demir ve Çelik İşletmeleri, Karabük, Turkey (*Ingots, thin plates, rolled sections and bars*) (ISTANBUL)
- Tvornica Dizalica I. Ljevaonica "Vulkan", Rijeka II, Yugoslavia. (*Castings*) (RIJEKA)
- Tweer, Reinhard, G.m.b.H., Sennestadt/Westf., Federal Republic of Germany. Works: Sennestadt. (*Castings*) (HANNOVER)
- Ube Industries, Ltd., Ube Machinery Works, Ube, Japan. (*Ingots, forgings and castings*) (SHIMONOSEKI)
- Uddeholms Aktiebolag, Uddeholm, Sweden.  
Works: Degerfors. (*Ingots, plates, sections and bars*) (GOTHENBURG)
- Works: Hagfors. (*Castings, ingots, forgings, bars and sections*) (GOTHENBURG)
- Works: Storfors. (*Seamless tubes*) (GOTHENBURG)
- Uematsu Kozai Kogyo Co., Ltd., Shibayama Works, Chiba Prefecture, Japan. (*Forgings*) (YOKOHAMA)
- Ugine-Aciers,  
73400-Ugine, France. (*Ingots, billets, bars, sections, castings and forgings*) (LYONS)
- Usine de Fos-sur Mer, France. (*Bars*) (MARSEILLES)
- Union Sidérurgique du Nord et de l'Est de la France, "USINOR".  
Usine de Dunkerque, Dunkerque (Nord). (*Ingots and plates*) (DUNKERQUE)
- GROUPE A.  
Usines de Denain, Denain (Nord). (*Ingots, thin plates and sections*) (VALENCIENNES)
- GROUPE B.  
Usines de Valenciennes, Valenciennes (Nord). (*Ingots, forgings, blooms, bars and sections*) (VALENCIENNES)
- GROUPE C.  
Usine de Longwy, 54 Longwy, France. (NANCY)  
Section Mont Saint Martin. (*Sections and plates*)  
Section Senelle. (*Ingots, blooms, bars and sections*)  
Usine de Thionville, 57 Thionville, France. (*Forgings and castings*) (NANCY)
- Union Steel Corporation of South Africa, Ltd. (Usco).  
Works: Vereeniging, Transvaal, South Africa. (*Ingots, billets, small sections, castings and rivet bars*) (VEREENIGING)



# APPROVED MANUFACTURERS AND PROVING ESTABLISHMENTS

- Unitcast Division of Midland-Ross of Canada Limited, Sherbrooke, Quebec. (*Castings*) (MONTREAL)
- United Engineers (Singapore) Pte. Ltd., Kampong Bahru Foundry. (*Castings*) (SINGAPORE)
- United States Steel Corporation, Pittsburgh, Pa., U.S.A.
- Clairton Works, Clairton, Pa. (*Ingots, blooms, bars and sections*) (CLEVELAND, O.)
- Duquesne Works, Duquesne, Pa. (*Ingots, billets, blooms and bars*) (CLEVELAND, O.)
- Fairfield Works, Alabama. (*Rolling mill and forgings*) (MOBILE)
- Fairless Works, Fairless Hills, Pa. (*Thin plates, bars and sections*) (PHILADELPHIA)
- Gary Works, Gary, Ind. (*Billets, blooms, plates, sections, bars and forgings*) (CHICAGO)
- Homestead District Works, Pa., including McKees Rock Works. (*Ingots, billets, blooms, slabs, plates, sections and forgings*) (CLEVELAND, O.)
- Irvin Works, Dravosburg, Pa. (*Rolling mills for thin plates*) (CLEVELAND, O.)
- McDonald Mills, Youngstown. (*Rolling mills for bars and sections*) (CLEVELAND, O.)
- Ohio Works, Youngstown. (*Ingots, billets and blooms*) (CLEVELAND, O.)
- South Works, South Chicago, Ill. (*Plates, sections and bars*) (CHICAGO)
- Texas Works, Baytown, Texas. (*Plates*) (CLEVELAND, O.)
- Usinas Siderurgicas de Minas Gerais S.A., Belo Horizonte, Estado de Minas Gerais, Brazil.
- Works: Ipatinga, Estado de Minas Gerais. (*Ingots, slabs and plates*) (RIO DE JANEIRO)
- Usines à Tubes de la Meuse, Flémalle-Haute, Belgium. (*Seamless and welded tubes*) (ANTWERP)
- V.W. Werke Vincenz Wiederholt, Holzwickede, Federal Republic of Germany. (*Electric resistance welded tubes*) (DORTMUND)
- VALLOUREC.
- Usine d'Anzin-Anzin (Nord), France. (*Seamless tubes*) (VALENCIENNES)
- Usine d'Aulnoye, Aulnoye (Nord), France. (*Weldless rolled and drawn tubes*) (VALENCIENNES)
- Varde Staalvaerk, Varde, Denmark. (*Ingots and castings*) (ODENSE)
- VEB Magdeburger Armaturenwerke, "Karl Marx", Magdeburg, German Democratic Republic. (*Castings*) (BERLIN)
- VEB Maschinenfabrik und Eisengiesserei Dessau, Dessau, German Democratic Republic. (*Castings*) (BERLIN)
- VEB Qualitats- und Edelstahl-Kombinat Stahl- und Walzwerk Groditz, 8402 Groditz, German Democratic Republic. (*Forgings and castings*) (BERLIN)
- VEB Qualitats- und Edelstahl-Kombinat Stahl- und Walzwerk Brandenburg, German Democratic Republic
- Works: Brandenburg. (*Ingots*) (BERLIN)
- Works: Ilsenburg. (*Rolling mill for plates*) (BERLIN)
- VEB Schwermaschinenbau-Kombinat "Ernst Thälmann", Magdeburg-Buckau, German Democratic Republic. (*Ingots and forgings*) (BERLIN)
- Vecor Heavy Engineering, Ltd., Vanderbijlpark, Transvaal, South Africa. (*Castings*) (VEREENIGING)
- Vereinigte Österreichische Eisen-und-Stahlwerke-Alpine Montan Aktiengesellschaft Linz.
- Works: Donauwitz, Styria. (*Sections, strip and bars*) (VIENNA)
- Works: Kindberg-Krieglach, Styria. (*Rolling mills for small sections, bars and strip*) (VIENNA)
- Works: Liezen, Styria. (*Ingots for forgings, castings*) (VIENNA)
- Works: Linz a.d. Donau, Upper Austria. (*Plates, forgings and castings*) (VIENNA)
- Works: Traisen, Lower Austria. (*Castings*) (VIENNA)
- Vickers Hadwa Pty., Ltd., Perth, W. Australia. (*Castings*) (FREMANTLE)
- Vickers Ruwolt Pty., Ltd., Richmond, Melbourne, Australia. (*Steel castings and ingots*) (MELBOURNE)
- Victoria Machinery Depot Co., Ltd., Victoria, B.C., Canada. (*Castings*) (VANCOUVER)
- Villa, Giovanni, S.p.A., Officine Meccaniche-Fucinati-Stampati, Milan, Italy. (*Forgings*) (MILAN)
- Viomichania Chalyvon Ltd., Athens, Greece. (*Castings*) (PIREUS)
- Vitkovické Železářny a Strojirny Klementa Gottwalda, národní podnik (The Vitkovice Steel and Engineering Works of Klement Gottwald, National Corporation), Ostrava 10, Czechoslovakia. (*Castings, forgings, plates, sections, bars and seamless tubes*) (VIENNA)
- Vizcaya, Altos Hornos de, S.A., Fabrica de Sagunto, Sagunto, Spain. (*Ingots, plates, bars and sections*) (VALENCIA)
- Vizcaya, Sociedad Altos Hornos de, Bilbao, Spain. (*Ingots, bars, sections, forgings and plates up to 10 mm thick*) (BILBAO)
- Voith, J. M., G.m.b.H., Heidenheim, Federal Republic of Germany. (*Steel castings*) (STUTTGART)
- Von Roll A.-G., Gerlafingen, Switzerland. (*Ingots, round bars and forgings*) (WINTERTHUR)
- Východoslovenské Železiarne, národný podnik (East Slovak Steelworks, National Corporation), Košice, Czechoslovakia. (*Slabs*) (VIENNA)
- Wagner-Biro Aktiengesellschaft, Werk Wien, Austria. (*Castings*) (VIENNA)
- Wakamatsu Sharyo Co. Ltd., Kitakyushu, Japan. (*Small castings*) (SHIMONOSEKI)
- Walkers Ltd., Maryborough, Queensland, Australia. (*Forgings and castings*) (BRISBANE)
- Walworth Alloyco and Grove International S.p.A. Stabilimento di Napoli, Naples. (*Castings*) (NAPLES)
- Washington Iron Works, Seattle, Wash., U.S.A. (*Castings*) (SEATTLE)
- Wasino Machine Co., Ltd.,
- Imamura Plant, Anjo, Japan. (*Castings*) (NAGOYA)
- Komaki Plant, Komaki, Japan. (*Small castings*) (NAGOYA)

# LLOYD'S REGISTER OF SHIPPING

- Waso-verken, A/B., Klavrestrom, Sweden. (*Small castings*) (GOTHENBURG)
- Watanabe Steel Works Co., Ltd., Tokyo, Japan. (*Castings*) (YOKOHAMA)
- Welmet Industries Ltd., Welland, Ontario, Canada. (*Castings*) (TORONTO)
- Western Canada Steel Ltd., (Vancouver Rolling Mills Ltd.,) Vancouver, B.C., Canada. (*Sections and bars*) (VANCOUVER)
- Wood, Alan, Steel Company, Conshohocken, Pa., U.S.A. (*Blooms, billets and plates*) (PHILADELPHIA)
- Wurth, Société Anonyme des Anciens Etablissements Paul, Luxembourg. (*Castings*) (NANCY)
- Yamato Kogyo Co., Ltd., Himeji, Japan. (*Castings*) (KOBE)
- Yamato Steel Works, Ltd., Osaka, Japan. (*Ingots, sections and plates*) (OSAKA)
- Yamazaki Machinery Mfg. Co. Ltd., Shiga Prefecture, Japan. (*Small forgings*) (OSAKA)
- Yonago Steel Works, Ltd., Yonago, Japan. (*Castings*) (KOBE)
- Zaklady Mechaniczne Im. Gen. K. Swierczewskiego, Elblag, Poland. (*Castings*) (GDANSK)
- Zaklady Metalurgiczne, Poznan, "Pomet" Poznan, ul Krancowa 15, Poland. (*Castings*) (GDANSK)
- Zaklady Urzadzen Chemicznych i Armatury Przemyslowej, Kielce, Poland. (*Castings*) (KATOWICE)
- Zaklady Urzadzen Technicznych "Zgoda", Swietochlowice, Poland. (*Forgings*) (KATOWICE)
- Združeno Podjetje Slovenke Zelezarne, Zelezarna, Jesenice, Yugoslavia. (*Plates, bars, sections and castings*) (SPLIT)
- Združeno Podjetje Slovenske Željezarne, Željezarna Ravne, Ravne na Koroškem, Yugoslavia. (*Castings, forgings, billets and bars*) (RIJEKA)
- Zelezarny Bila Cerkev, narodni podnik, (Steelworks "Bila Cerkev" National Corporation), Czechoslovakia. *Works: Chomutov. (Seamless tubes) (VIENNA)*  
*Works: Hradek u Rokycan. (Ingots and bars) (VIENNA)*
- Zelezárny a drátovny Bohumin, národní podnik (Iron Works and Wire Works Bohumin, National Corporation), Bohumin, Czechoslovakia. (*Small sections and bars*) (VIENNA)
- Željezara "Boris Kidric", Niksic, Yugoslavia. (*Plates and castings*) (SPLIT)
- Željezara Sisak, Sisak-Predgradje, Yugoslavia. (*Seamless tubes*) (RIJEKA)



# APPROVED MANUFACTURERS AND PROVING ESTABLISHMENTS

## FIRMS IN COUNTRIES OTHER THAN GREAT BRITAIN AND IRELAND (ARRANGED ACCORDING TO SURVEYING DISTRICTS)

### Adelaide

Bradford Kendall Ltd., Adelaide, South Australia. (Castings)  
Mason & Cox Pty. Ltd., Adelaide, S. Australia. (Castings)

### Alexandria

Egyptian Iron & Steel Co., S.A.E., Helwan, Arab Republic of Egypt. (Plates)

### Amsterdam

Dijkers, G., & Co., N.V., Hengelo, Holland. (Small castings)  
Estel, Hoogovens Ijmuiden B.V., Ijmuiden, Holland. (Plates and sections)  
Utrecht, Holland. (Rolling mill for bars)  
Staalgieterij SMDK, N.V., Utrecht, Holland. (Ingots and castings)

### Antwerp

Aciéries Leonard-Giot-Allard S.A., Turnhout, Belgium. (Small castings)  
Allard, Usines & Aciéries, Société Anonyme, Mont-sur-Marchienne, near Charleroi, Belgium. (Castings)  
Baume, Société Anonyme des Forges et Laminoirs de, Haine St. Pierre, Belgium. (Ingots, bars and sections)  
Boël, Usines Gustave, Soc. An., La Louvière, Belgium. (Ingots, forgings, castings, plates and universal flats)  
Boom, Travaux Métalliques de, Société Anonyme, Boom, Belgium. (Small castings)  
Charleroi, Société Anonyme de la Fabrique de Fer de, Charleroi, Belgium. (Ingots, slabs and plates)  
Clabecq, Société Anonyme Forges de, Clabecq, Belgium. (Ingots, plates, bars and sections)  
S.A. Cockerill-Ougrée-Providence-Esperance-Longdoz, Seraing, Belgium.  
Group I: A—Département Aciéries et Laminoirs d'Ougrée, Seraing. (Ingots, blooms, billets, slabs and thin plates)  
B—Département Aciéries et Laminoirs de Chertal. (Ingots and thin plates)  
C—Département Forges, Fonderies et Aciérie Speciale. (Castings and forgings)  
Group Marchienne-Athus: S.A. Cockerill, Marchienne-au-Pont. (Sections, bars, ingots and blooms)  
Hainaut-Sambre, Société Métallurgiques, S.A., Couillet, Belgium.  
Division de Couillet. (Ingots, blooms, sections, flats, forgings, castings and bars)  
Division de Montignies et Chatelinlaui. (Rolling mill)

### Antwerp—continued

Haine St. Pierre et Lesquin, Aciéries de, Société Anonyme, Haine St. Pierre, Belgium. (Castings)  
Henricot, Usines Emile, Court St. Etienne, Belgium. (Castings)  
Jemappes, Société Anonyme Forges et Laminoirs de, Jemappes, near Mons, Belgium. (Ingots, blooms and bars)  
Leonard-Giot, Société Anonyme Usines & Aciéries Marchienne-au-Pont, Belgium. (Castings)  
SIDMAR, Maritieme Staalnijverheid, Gent, Belgium. (Plates)  
Usines à Tubes de la Meuse, Flémalle-Haute, Belgium. (Seamless and welded tubes).

### Augsburg

Decker, Gebrüder, Betrieb 1, Eisen- & Stahlgiesserei, Nürnberg 2, Ostendstr. 84, Federal Republic of Germany. (Electric steel castings)  
Krauss-Maffei, A.G., München-Allach, Federal Republic of Germany. (Castings)  
Maximilianshütte, Eisenwerk-Gesellschaft m.b.H., Sulzbach-Rosenberg, Bavaria, Federal Republic of Germany, Haidhof Works. (Ingots, billets, bars, small sections and thin plates)

### Baltimore, Md.

Bethlehem Steel Co., Sparrows Point, Md., U.S.A. (Plates)

### Barcelona

Funderia S.A. de, Manresa, Spain. (Castings)  
Hansa-Hierros y Aceros Moldeados S.A., Ermengarda, Barcelona, Spain. (Forged bars)  
Hierros y Aceros Industriales S.A., San Adrian de Besos, Barcelona, Spain. (Small castings)  
Industrias del Besos, S.A., Barcelona, Spain. (Small sections and bars)  
Industrias Mecanicas, Sociedad Anonima, Barcelona, Spain. (Castings)  
Material y Construcciones S.A., Barcelona, Spain. (Castings)  
Sucesora de Aceros Electricos S.A., Barcelona, Spain. (Castings)  
Torras, Herreria y Construcciones S.A., Calle Pamplona 43, Barcelona, Spain. (Small sections)

### Bergen

Stavanger Staal A.S., Jorpeland, near Stavanger, Norway. (Castings)



**Berlin**

- Borsig G.m.b.H., 1 Berlin-Tegel (Gruppe Deutsche Babcock), German Democratic Republic. (*Castings*)
- VEB Magdeburger Armaturenwerke "Karl Marx", Magdeburg, German Democratic Republic. (*Castings*)
- VEB Maschinenfabrik und Eisengiesserei Dessau, Dessau, German Democratic Republic. (*Castings*)
- VEB Qualitats- und Edelstahl-Kombinat, Stahl- und Walzwerk Brandenburg, German Democratic Republic  
Works: Brandenburg (*Ingots*)  
Works: Isenburg (*Rolling mill for plates*)
- VEB Qualitats- und Edelstahl-Kombinat, Stahl- und Walzwerk Groditz, 8402 Groditz, German Democratic Republic. (*Forgings and castings*)
- VEB Schwermaschinenbau-Kombinat "Ernst Thalmann", Magdeburg-Buckau, German Democratic Republic. (*Ingots and forgings*)

**Bilbao**

- Acerias y Forjas de Azcoitia, Azcoitia Guipuzcoa, Spain. (*Ingots and small rolled bars*)
- Aceros y Fundiciones del Norte Pedro Orbegozo y Cia. S.A., Hernani (Guipuzcoa), Spain. (*Ingots, forgings and rolled bars*)
- Ampo S.C.I., Idiazabal, Guipuzcoa. (*Castings*)
- Amurrio, S.A., Talleres de, Amurrio, Alava, Spain. (*Steel castings*)
- ARANZABAL S.A., Vitoria Alava, Spain. (*Small castings*)
- Astilleros Españoles, S.A.,  
Factoria de Asua (Near Bilbao), Vizcaya, Spain. (*Castings*)  
Factoria de Reinosa, Spain. (*Ingots, forgings, castings, plates and sections*)
- Azma S.A., Getafe, Madrid, Spain. (*Bars and sections*)
- Babcock & Wilcox, Sociedad Española de Construcciones, Spain.  
Head Office: Calle Ercilla 1, Bilbao.  
Works: Galindo-San Salvador del Valle. (Vizcaya) (*Castings, ingots and forgings*)
- Construccion y Auxiliar de Ferrocarriles, Beasain, Guipuzcoa, Spain. (*Small castings and forgings*)
- Cooperativa Industrial Electrodo y Aceros, Boó, Santander, Spain. (*Castings*)
- Crane-Fisa S.A., Bilbao, Spain. (*Small castings*)
- Echevarria, Sociedad Anonima, Bilbao, Spain. (*Small sections and bars, small forgings and ingots*)
- Echeverria, Patricio, S.A., Legazpia, Spain. (*Ingots, blooms, forgings and small bars*)
- Eguiluz, Talleres, Miranda del Ebro, Burgos, Spain. (*Castings*)
- Ferretera Montanesa S.A., Torrelavega, Spain. (*Castings*)
- Forjas Alavesas, S.A., Vitoria, Spain. (*Ingots, rolled bars and forgings*)

**Bilbao—continued**

- Fundiacero S.A., Miranda de Ebro Works, Bilbao, Spain. (*Castings*)
- Fundiciones Arriaran S.A., Lazcano, Guipuzcoa, Spain. (*Castings*)
- Fundiciones del Estanda S.A., Beasain, Spain. (*Castings*)
- Fundiciones Echevarria S.A., Beasain, Guipuzcoa, (*Ingots, small rolled bars and castings*)
- Fundiciones Especiales Zaragoza S.A., Zaragoza, Spain. (*Castings*)
- Guivisa S.A., Basauri, Bilbao, Spain (*Castings*)
- Llodio, Aceros de, S.A., Llodio, near Bilbao, Spain. (*Castings, ingots, forgings and rolled bars*)
- Luzuriaga, Victorio, S.A., Pasajes, Guipuzcoa, Spain.  
Works: Usurbil, Guipuzcoa. (*Castings*)
- Nueva Montana Quijano S.A., Nueva Montana, Santander, Spain. (*Castings*)
- Olarra S.A., Larrondo, Lujúa, Vizcaya, Spain. (*Ingots and rolled bars*)
- Siderurgica Ebroacero S.A., Zaragoza, Spain. (*Castings*)
- Sifema S.A. Bilbao, Spain. (*Steel castings*)
- Talleres de Deusto, S.A., Luchana, Bilbao, Spain. (*Ingots, castings and small forgings*)
- Vizcaya, Sociedad Altos Hornos de, Bilbao, Spain. (*Ingots, bars, sections, forgings and plates up to 10 mm thick*)

**Bombay**

- Godrej & Boyce Mfg. Co. Pvt. Ltd., Bombay, India. (*Steel castings*)
- Mahindra Ugine Steel Co., Ltd., Khapoli Works, Bombay, India. (*Bars, billets and sections*)
- Mukand Iron & Steel Works, Ltd., Kurla, Bombay 70, India. (*Castings*)

**Bremen**

- Bremer Vulkan, Schiffbau und Maschinenfabrik, Bremen-Vegesack, Federal Republic of Germany. (*Castings*)
- Klöckner-Werke A.G., Hutte Bremen, Federal Republic of Germany. (*Plates*)
- Sande, Giesserei, Sande-Oldenburg, Federal Republic of Germany. (*Castings*)

**Brisbane**

- Bradford Kendall Ltd., Runcorn, Brisbane, Queensland, Australia. (*Castings*)
- Commonwealth Steel (Moorooka) Pty. Ltd., Moorooka, Brisbane, Queensland, Australia. (*Castings*)
- Walkers Ltd., Maryborough, Queensland, Australia. (*Forgings and castings*)



# APPROVED MANUFACTURERS AND PROVING ESTABLISHMENTS

## Buenos Aires

- Acerias Bragado S.A.I.C. and Aceros Bragado S.A.I.C., Bragado, Argentina. (*Castings*)  
 Acindar S.A., Planta de Aceros Finos y Especiales, Villa Constitucion, Santa Fe, Argentina. (*Ingots, forgings and forged bars*)  
 Astilleros Rio Santiago, Ensenada, Buenos Aires, Argentina. (*Steel castings*)  
 Herchamet S.A.I.C., Fundicion Electrica de Aceros, Velez Sarfield, Rosario, Argentina. (*Castings*)

## Busan

- Dai Han Anchor Chain Mfg. Co. Ltd., Seoul, Korea. (*Castings*)  
 Dongkuk Steel Mill Co., Ltd., Busan Works, Busan, Korea. (*Plates*)  
 Pohang Iron and Steel Co., Ltd., Pohang Works, Pohang, Korea. (*Rolling mill for plates*)  
 Pusan Pokum Ind. Co. Ltd., Busan, Korea. (*Castings*)

## Calcutta

- Bhartia Electric Steel Co., Ltd., Calcutta, India. (*Castings*)  
 Burn & Co., Ltd., Howrah, India. (*Castings*)  
 Electrosteel Castings Ltd., Khardah, West Bengal, India. (*Castings*)  
 Hindustan Steel Ltd.,  
     Bhilai Steel Project, Bhilai, Madhya Pradesh, India. (*Ingots, blooms, billets and sections*)  
     Durgapur Steel Plant, West Bengal, India. (*Blooms, billets, bars and sections*)  
     Rourkela, Orissa, India. (*Ingots, slabs and plates*)  
 Indian Iron & Steel Co., Ltd.,  
     Burnpur Works, Burnpur, West Bengal, India. (*Sections and angles*)  
     Kulti Iron Works, Kulti, India. (*Castings*)  
 Indian Tube Company, Ltd., Jamshedpur, India. (*Seamless tubes and electric resistance welded tubes*)  
 Kumardhubi Engineering Works Ltd., P.O. Box Kumardhubi Dist. Dhanbad (Bihar), India. (*Castings*)  
 Metal & Steel Factory, Ishapore, West Bengal, India. (*Ingots, blooms, billets, forgings, castings and bars*)  
 National Iron & Steel Co., Ltd., Stephen House, Calcutta, 1, India. (*Castings*)  
 Tata Engineering & Locomotive Co., Ltd., Jamshedpur 4, India. (*Castings*)  
 Tata Iron & Steel Co., Ltd., Jamshedpur, India. (*Blooms, billets, bars, plates and sections*)

## Callao

- Empresa Siderurgica del Peru, Siderperu, Chimbote, Peru. (*Plates*)

## Chicago

- Bethlehem Steel Co., Burns Harbour Plant, Chesterton, Indiana, U.S.A. (*Rolling mill for plates*)  
 Falk Corporation, Milwaukee, Wis., U.S.A. (*Castings*)  
 Finkl, A., & Sons Company, Chicago, Illinois, U.S.A. (*Forgings*)  
 Republic Steel Corporation, Chicago Plant, Chicago, Illinois, U.S.A.  
     Works: 118th Street, Chicago Rolling Mills, East Chicago, Ind. (*Bars*)  
 U.S. Steel Co., Pittsburgh, Pa., U.S.A.  
     Gary Works, Gary Ind. (*Billets, blooms, plates, sections, bars and forgings*)  
     South Works, South Chicago, Illinois. (*Plates, sections and bars*)

## Cleveland, O.

- Armco Steel Corporation, Houston Plant, Texas. (*Plates and sections*)  
 Bethlehem Steel Corp.  
     Johnstown Plant, Johnstown, Pa., U.S.A. (*Ingots, billets, slabs, plates and bars*)  
     Lackawanna, N.Y., U.S.A. (*Ingots, blooms, billets, bars, plates and sections*)  
 Colt Industries, Crucible, Inc., P.O. Box 226, Midland, Pa. 1505g., U.S.A. (*Ingots, slabs, billets, hot rolled and cold drawn bars*)  
 Edgewater Corporation, Oakmont, Pennsylvania, U.S.A. (*Ingots and forgings*)  
 Farrell-Cheek Steel Co., Sandusky, Ohio, U.S.A. (*Steel castings*)  
 Jones & Laughlin Steel Corporation, Pittsburgh, Pa., U.S.A. (*Plates, sections, bars and tubes*)  
 Latrobe Forge & Spring, Inc., Latrobe, Pa., U.S.A. (*Ingots and forgings*)  
 National Forge Co.  
     Erie Division, Erie, Pennsylvania, U.S.A. (*Ingots, forgings and castings*)  
     Irvine, Warren County, Pennsylvania, U.S.A. (*Ingots and forgings*)  
 Sandusky Foundry & Machine Co., Sandusky, Ohio, U.S.A. (*Castings*)  
 Sharon Steel Corporation, Roemer Works, Farrell, Pa., U.S.A. (*Ingots, blooms and billets*)  
 United States Steel Corporation, Pittsburgh, Pa., U.S.A.  
     Clairton Works, Clairton, Pa. (*Ingots, blooms, bars and sections*)  
     Duquesne Works, Duquesne, Pa. (*Ingots, billets, blooms and bars*)  
     Homestead District Works, Pa., (including McKees Rock Works). (*Ingots, billets, blooms, slabs, plates, sections and forgings*)



**Cleveland O.—continued**

- Irvin Works, Dravosburg, Pa. (*Rolling mills for thin plates*)  
 McDonald Mills, Youngstown. (*Rolling mills for bars and sections*)  
 Ohio Works, Youngstown. (*Ingots, billets and blooms*)  
 Texas Works, Baytown, Texas. (*Plates*)

**Cologne (Köln)**

- Albert Hoffmann K.G., Eschweiler, Federal Republic of Germany. (*Small ingots, forgings and castings*)  
 Dorrenberg, Ed., Sohne Edelstahlwerke, Runderoth/Rheinland, Federal Republic of Germany. (*Castings*)  
 Eschweiler Bergwerks-Verein Hüttenbetriebe, Eschweiler-Aue, Federal Republic of Germany. (*Ingots and seamless tubes*)  
 Gusstahlwerke Risch K.G., Bergisch-Gladbach, Federal Republic of Germany. (*Electric steel castings*)  
 Klockner-Werke A.G., Mannstaedt-Werke, Troisdorf, Federal Republic of Germany. (*Rolling mills for sections*)  
 Schmidt & Clemens, Edelstahlwerk, Kaiserau b/Engelskirchen Bez. Köln, Federal Republic of Germany. (*Ingots, forgings, castings and bars*)

**Copenhagen**

- A/S Burmeister & Wain, Motor-og Maskinfabrik af 1971, Copenhagen, Denmark. (*Ingots, forgings and castings*)  
 Danske, (Det), Staalvalsevaerk A/S., Frederiksvaerk, Denmark. (*Plates, sections and bars*)  
 Helsingors Skibsvaerft-og Maskinbyggeri A/S., Aktieselskabet, Elsinore, Denmark. (*Forgings and castings*)

**Dortmund**

- Bischoff-Werke K.G., AB Stahlgiesserei Ludinghausen/Westphalia, Federal Republic of Germany. (*Castings*)  
 Boschgotthardshütte, Otto Breyer G.m.b.H., Edelstahlwerk-Press. u. Hammerwerk-Mechanische Werkstätten, Hüttental-Weidenau, Federal Republic of Germany. (*Ingots and forgings*)  
 Breitenbach, Ed., G.m.b.H., Hüttental-Weidenau/Sieg, Federal Republic of Germany. (*Castings*)  
 Edelstahlwerke Buderus A.G., Wetzlar, Federal Republic of Germany. (*Ingots, blooms, billets, bars and forgings*)  
 Edelstahlwerk Witten A.G., Witten-Ruhr, Federal Republic of Germany. (*Ingots, billets, bars, forgings and narrow flats*)  
 Eisenwerk Bohmer, Witten, Ruhr, Dortmund, Federal Republic of Germany. (*Castings*)  
 Eisenwerk Geweke, R. & C. R. Lange K.G., Hagen-Haspe, Federal Republic of Germany. (*Electric steel castings*)  
 Eisenwerk Rödinghausen K.G., Lendringsen Krs. Iserlohn, Federal Republic of Germany. (*Castings*)

**Dortmund—continued**

- Estel, Hoesch Hüttenwerke, A.G., Dortmund, Federal Republic of Germany.  
 Werk Phoenix Hörde, Dortmund-Hörde. (*Ingots, plates and castings*)  
 Werk Union, Dortmund. (*Bars and sections*)  
 Werk Westfalenhütte, Dortmund. (*Ingots, billets, plates, bars and sections*)  
 Gottwald, Leo Werk Hattingen, Ruhr, Federal Republic of Germany. (*Small forgings*)  
 Gusstahlwerk Carl Bönnhoff, Wetter/Ruhr, Federal Republic of Germany. (*Ingots and castings*)  
 Knorr-Bremse G.m.b.H., Volmarstein-Schmandbruch, Federal Republic of Germany. (*Castings*)  
 Kruiner Gusstahlwerk, Gevelsberg, Federal Republic of Germany. (*Castings*)  
 Paderwerk Gebr. Benteler, Schlossneuhau, Federal Republic of Germany. (*Seamless tubes*)  
 Schutte, Meyer & Co., G.m.b.H., Letmathe, Westphalia, Federal Republic of Germany. (*Small castings*)  
 Stahlwerke Südwestfalen, A.G.  
 Werk Geisweid, Geisweid, Kries Siegen, Federal Republic of Germany. (*Ingots, bars, billets, thin plates, sheets and coils*)  
 Werksgruppe Geisweid, Works Niederschelden, Federal Republic of Germany. (*Ingots and slabs*)  
 Werksgruppe Hagen, Werk Wehringhausen, Hagen, Federal Republic of Germany. (*Ingots, bars and forgings*)  
 Thyssen Henrichshütte, Hattingen, Ruhr, Federal Republic of Germany. (*Ingots, plates, forgings and castings*)  
 V.W. Werke Vincenz Wiederholt, Holzwickede, Federal Republic of Germany. (*Electric resistance welded tubes*)

**Dunedin**

- Dunedin Engineering & Steel Co., Ltd., Dunedin, New Zealand. (*Castings*)

**Dunkerque**

- Creusot Loire, Usine des Dunes, Malo les Bains (Nord), France. (*Ingots, billets, blooms, bars and forgings*)  
 Generale d'Hydraulique et de Mecanique, Usine Metallurgiques de Marquise Rinxent, Pas de Calais, France. (*Castings*)  
 Paris et d'Outreau, Aciéries de, Société Anonyme, Usines d'Outreau Pas de Calais, France. (*Castings*)  
 Union Siderurgique du Nord et de l'Est de la France, "USINOR", Usine de Dunkerque, Dunkerque (Nord), France. (*Ingots and plates*)

**Durban**

- Pinetown Engineering Foundry Co. (Pty.) Ltd., Pinetown, Natal, South Africa. (*Castings*)



## APPROVED MANUFACTURERS AND PROVING ESTABLISHMENTS

### Dusseldorf

August Thyssen-Hütte A.G., Duisburg-Hamborn, Federal Republic of Germany.

Area Hamborn, Steelworks Beeckerwerth, Bruckhausen and Ruhrort. (*Ingots, billets, slabs, plates and sections*)

Duisburg Huttenheim. (*Plates*)

Bergische Stahlindustrie K.G., Remscheid, Federal Republic of Germany. (*Castings*)

Deutsche Edelstahlwerke A.G., Krefeld, Federal Republic of Germany. (*Ingots, forgings and rolled materials*)

Fried. Krupp Hüttenwerke A.G., Bochum, Federal Republic of Germany.

*Works:* Bochum. (*Ingots, plates, forgings, castings and bars*)

*Works:* Rheinhausen. (*Ingots, bars and sections*)

Grossmann, C., Eisen-und Stahlwerk A.G., Solingen-Wald, Federal Republic of Germany. (*Castings*)

Gutehoffnungshütte Sterkrade A.G., Werk Sterkrade, Oberhausen-Sterkrade, Federal Republic of Germany. (*Forgings*)

Mannesmann A.G. Hüttenwerke, Duisburg-Huckingen, Federal Republic of Germany. (*Ingots, slabs and bars*)

Mannesmannrohren-Werke G.m.b.H., Dusseldorf, Federal Republic of Germany. (*Seamless and welded tubes*)

Niederrheinstahl G.m.b.H., Stahl- und Röhrenwerke, Dinslaken, Federal Republic of Germany. (*Ingots, billets for tubes and bars*)

Rheinstahl Giesserei A.G., Gussstahlwerke Gelsenkirchen, Federal Republic of Germany. (*Castings*)

Rheinstahl Giesserei A.G., Gussstahlwerke Oberkassel, Dusseldorf-Oberkassel, Federal Republic of Germany. (*Ingots and castings*)

Rheinstahl Giesserei A.G., Friedrich Wilhelms-Hütte, Mülheim/Ruhr, Federal Republic of Germany. (*Castings*)

Stahl- u. Röhrenwerke Reisholz G.m.b.H.,

*Works:* Reisholz. (*Ingots and seamless tubes*)

Stahlwerke Bochum A.G., Bochum, Federal Republic of Germany. (*Castings, rolled materials and plates*)

Thyssen Niederrhein A.G., Hutten-und Walzwerke, Werk Duisburg, Federal Republic of Germany. (*Rolling mill for narrow flats and sections*)

Thyssen Niederrhein A.G., Hutten-und Walzwerke, Oberhausen, Federal Republic of Germany. (*Ingots, plates, sections and bars*)

### El Ferrol

Astilleros y Talleres del Noroeste S.A., El Ferrol del Caudillo, Spain. (*Small forgings and small castings*)

Empresa Nacional Bazan, El Ferrol del Caudillo, Spain. (*Castings*)

### Fremantle

Australian Iron & Steel Pty. Ltd., Steelworks, Kwinana, W. Australia. (*Small bars and sections*)

Bradford Kendall Ltd., South Beach, South Fremantle, Australia. (*Castings*)

Vickers Hadwa Pty. Ltd., Perth, W. Australia. (*Castings*)

### Galatz

Combinatul Siderurgic Gheorghiu Dej, Galatz, Rumania. (*Plates*)

Interprinderea de Constructii de Masini, Resitza. (*Castings and forgings*)

Masini, Grele, Usina de, Bucurest, Rumania. (*Forgings*)

### Galveston

Cameron Iron Works Inc., Houston, Texas, U.S.A. (*Ingots and forgings*)

### Gdansk

Zaklady Mechaniczne Im. Gen. K., Swierczewskiego, Elblag, Poland. (*Castings*)

Zaklady Metalurgiczne Poznan, "Pomet", Poznan ul Krancowa 15, Poland. (*Castings*)

### Genoa

A.S.S.A. Acciaierie di Susa Società Anonima, Turin, Italy. *Head Office:* Turin. *Works:* Susa. (*Castings*)

FIAT, Società per Azioni, Sezione Ferriere Piemontesi, Turin, Italy. (*Ingots, plates, sections; also seamless and welded tubes*)

Fit Ferrotubi-Fabbrica Italiana Tubi Ferrotubi, Italy. (*Ingots, billets and seamless tubes*)

Fonderia Acciaieria Giovanni Mandelli, Turin, Italy. (*Castings*)

"Italsider" S.p.A., *Head Office:* Via Corsica 4, Genoa, Italy.

Centro Siderurgico "Oscar Sinigaglia" Campi Works, (*Ingots, forgings, plates and castings*)

Centro Siderurgico "Oscar Sinigaglia", Oscar Sinigaglia Works, Genoa-Cornigliano. (*Ingots, slabs and plates*)

Nazionale "Cogne", S.p.A. *Head Office:* Turin, Italy. *Works:* Aosta. (*Ingots, blooms, billets and bars*)

### Gijon

Duro-Felguera, Sociedad Metalúrgica, La Felguera, Asturias, Spain. (*Castings*)

Empresa Nacional Siderurgica, S.A. (ENSIDESA) Factoria de Avilés, Spain. (*Ingots, slabs and billets for re-rolling, plates and sections*)

Fabrica de Gijon, Gijon, Spain. (*Rivet bars and ingots*)

Fabrica de La Felguera, La Felguera, Asturias, Spain. (*Ingots, billets, plates and sections*)

Fabrica de Mieres, Asturias, Spain. (*Sections, bars and plates up to 15 mm in thickness*)

Factoria de Verina-Gijon, Spain. (*Ingots, billets, slabs and plates*)

Metalurgica del Nalon S.A. (MENASA), Lada, Spain. (*Castings*)

Talleres de Moreda S.A., Gijon. (*Forgings*)

Trubia, Fábrica Nacional de, Trubia Asturias, Spain. (*Castings and forgings*)



**Gothenburg**

- Björneborgs Jernverks Aktiebolag, Björneborg, Sweden.  
(*Ingots and forgings*)
- Bofors Aktiebolaget, Bofors, Sweden. (*Ingots, forgings, castings and rolled bars*)
- Motala Verkstad, A/B, Motala Verkstad, Sweden.  
(*Ingots and castings*)
- Svenska Kullagerfabriken A/B, Hellefors Jernverk, Hällefors, Sweden. (*Ingots and bars*)
- Uddeholms Aktiebolag, Uddeholm, Sweden.  
Works at Degerfors. (*Ingots, plates, sections and bars*)  
Works at Hagfors. (*Castings, ingots, forgings, bars and sections*)  
Works at Storfors. (*Seamless tubes*)
- Waso-verken, A/B, Klavreström, Sweden. (*Small castings*)

**Haifa**

- Associated Steel Foundries Co., Ltd., Natanya, Isarel.  
(*Castings*)

**Halifax, N.S.**

- Hawker Siddeley Canada Ltd., Trenton Works, Trenton, N.S. (*Forgings*)
- Maritime Steel and Foundries, Ltd., New Glasgow, N.S.  
(*Small castings*)
- Sydney Steel Corporation, Sydney, N.S. (*Ingots, billets and sections*)

**Hamburg**

- Ellerbrock, Hans, Stahlgiesserei und Maschinenfabrik, Hamburg, Federal Republic of Germany. (*Castings*)

**Hannover**

- Eisen-und Stahlwerk Pleissner G.m.b.H., Herzberg/Harz, Federal Republic of Germany. (*Castings*)
- Friedrich-Carl-Hütte G.m.b.H., Delligsen über Alfeld/Leine, Federal Republic of Germany. (*Castings*)
- Klockner Werke A.G., Georgsmarienhütte.  
Works: Georgsmarienhütte, Federal Republic of Germany. (*Ingots and bars*)  
Works: Osnabruck, Federal Republic of Germany. (*Forgings and castings*)
- Sollinger Hutte G.m.b.H., Uslar/Solling, Federal Republic of Germany. (*Castings*)
- Stahlwerke Peine-Salzgitter A.G.,  
Werk Giesserei Heerte, Federal Republic of Germany. (*Castings*)  
Werke Peine, Peine, Federal Republic of Germany. (*Ingots, billets, sections and bars*)  
Werk Salzgitter, Salzgitter-Drutte, Federal Republic of Germany. (*Ingots, plates, bars and sections*)
- Tweer, Reinhard, G.m.b.H., Sennestadt/Westf., Federal Republic of Germany. Works: Sennestadt. (*Castings*)

**Haren-Groningen**

- Ten Cate, Heerenveen, Holland. (*Small castings*)

**Helsinki/Helsingfors**

- Ahlstrom, A., Osakeyhtio, Karhulan Tehtaat, Karhula, Finland. (*Castings*)
- Ovako Oy, Imatra Steel Works, Imatra, Finland.  
(*Ingots, slabs, blooms, billets, bars, sections and castings*)
- Oy Stenborg, John, Ab, Helsinki, Finland. (*Small castings*)
- Oy Wärtsilä Ab, Steel Mill, Dalsbruk, Finland. (*Ingots, billets, bars and castings*)
- Raahe Oy, Raahe, Finland. (*Small castings*)
- Rauma-Repola Oy, Lokomon Tehtaat, Tampere, Finland.  
(*Ingots, forgings and castings*)
- Rautaruukki Oy, Raahe, Finland. (*Ingots and plates*)

**Hiroshima**

- Japan Steel Works Ltd., Hiroshima Works, Hiroshima, Japan. (*Forgings and castings*)
- Kotobuki Industries Co., Ltd., Hiro Works, Kure, Japan.  
(*Castings*)
- Mitsubishi Heavy Industries Ltd.  
Hiroshima Shipyard and Engine Works, Hiroshima, Japan. (*Ingots, castings and small forgings*)
- Mihara Machinery Works, Mihara, Japan. (*Castings and forgings*)
- Nisshin Steel Co. Ltd., Kure Works, Kure, Japan.  
(*Ingots, blooms, billets and strip*)

**Hong Kong**

- Cheoy Lee Shipyard, Lantau Island, Hong Kong.  
(*Castings*)

**Houston**

- Cabot Machinery Corp., Pampa, Texas. (*Forgings*)

**Istanbul**

- Denizcilik Bankasi T.A.O., Halic Yard Foundry, Turkey.  
(*Castings*)
- Eregli Demir ve Celik Fabrikalari T.A.S., Eregli, Turkey. (*Ingots and plates*)
- Makine ve Kimya Endustri, Celik Fabrikasi, Kirikkale, Turkey. (*Ingots, forgings, rolled sections and bars*)
- Turkiye Demir ve Celik Isletmeleri, Karabuk, Turkey.  
(*Ingots, thin plates, rolled sections and bars*)

**Jamshedpur**

- Heavy Engineering Corp. Ltd., Foundry Forge Plant, P. O. Dhurwa, Ranchi, India. (*Castings and forgings*)
- Himmat Steel Foundry Private Ltd., P.O. Kumhari, District Durg, M.P. (India). (*Castings*)

**Katowice**

- Huta 1-Maja, Gliwice, Poland. (*Ingots and forgings*)
- Huta Baildon, Katowice, Poland. (*Ingots, forgings and bars*)
- Huta Batory, Chorzow-Batory, Poland. (*Forgings, plates and tubes*)



# APPROVED MANUFACTURERS AND PROVING ESTABLISHMENTS

## Katowice—continued

Huta im Bieruta, Czestochowa, Poland. (*Seamless tubes and rolling mill for plates*)  
Huta Bobreck, Bytom, Poland. (*Ingots, slabs and blooms*)  
Huta im M. Buczka, Sosnowiec, Poland. (*Seamless tubes*)  
Huta Dzierzynski, Dabrowa Gornicza, Poland. (*Billets, sections and bars*)  
Huta Florian, Swietochlowice, Poland. (*Angles and bars*)  
Huta Jednosc, Siemianowice Slaskie, Poland. (*Ingots and seamless tubes*)  
Huta Kosciuszko, Chorzow, Poland. (*Billets, blooms, sections and rivet bars*)  
Huta Labedy, Labedy, Poland. (*Flats and sections*)  
Huta im. Lenina, Krakow, Poland. (*Ingots, slabs and plates*)  
Huta Malapanew, Ozimek k/Opola, Poland. (*Castings*)  
Huta Nowotko, Ostrowiec Swietokrzyski, Poland. (*Sections*)  
Huta Pokoj, Ruda Slaska, Poland. (*Plates, sections and small forgings*)  
Huta Stalowa Wola, Stalowa Wola, Poland. (*Castings, forgings, plates and sections*)  
Huta Warszawa, Warsaw, Poland. (*Ingots, forgings and rolled bars*)  
Huta Zawiercie, Zawiercie, Poland. (*Flats and bars*)  
Zaklady Urzadzen Chemicznych i Armatury Przemyslowej Kielce, Poland. (*Castings*)  
Zaklady Urzadzen Technicznych "Zgoda", Swietochlowice, Poland. (*Forgings*)

## Kiel

Nordische Stahlwerke, Bach & Co., Neumünster  
Federal Republic of Germany. (*Castings*)

## Kobe

Asano Tekkosho Co. Ltd., Saijo, Japan. (*Small forgings*)  
Hitachi Metals, Ltd., Yasugi Works, Yasugi, Japan. (*Ingots, bars and forgings*)  
Ishikawajima-Harima Heavy Industries Co., Ltd., Aioi Works, Aioi, Japan. (*Castings and forgings*)  
Japan Drop Forge Co., Ltd., Amagasaki, Japan. (*Small forgings*)  
Kamahara Steel Casting Manufacturing Co. Ltd., Kochi Works, Kochi-ken, Japan. (*Steel castings*)  
Kansai Tekko Co., Ltd., Amagasaki, Japan. (*Small forgings*)  
Kawasaki Steel Corporation.  
Fukiai Works, Kobe, Japan. (*Blooms and sections*)  
Mizushima Works, Mizushima, Japan. (*Ingots, forgings, castings, bars, plates and sections*)

## Kobe—continued

Kobe Steel Ltd.  
Amagasaki Works, Amagasaki, Japan. (*Ingots, sections and bars*)  
Kakogawa Works, Kakogawa, Japan. (*Ingots and plates*)  
Kobe Works, Kobe, Japan. (*Ingots, blooms, billets, bars and castings*)  
Takasago Works, Takasago, Japan. (*Ingots, forgings and castings*)  
Mitsubishi Heavy Industries Ltd.  
Kobe Shipyard & Engine Works, Kobe, Japan. (*Ingots, small forgings and castings*)  
Takasago Machinery Works, Takasago, Japan. (*Forgings*)  
Mitsui Shipbuilding & Engineering Co. Ltd., Tamano Works, Tamano, Japan. (*Ingots, forgings and castings*)  
Nippon Kokan Kabushiki Kaisha, Fukuyama Iron Works, Fukuyama, Japan. (*Ingots, blooms, sections and plates*)  
Nippon Satetsu Steel Co. Ltd., Shikama Works, Himeji, Japan. (*Ingots, bars and sections*)  
Nippon Steel Corporation, Hirohata Works, Hirohata, Japan. (*Ingots, billets, plates and sections*)  
Sanyo Special Steel Co. Ltd., Himeji, Japan. (*Ingots, forgings and rolled bars*)  
Sumitomo Electric Industries, Ltd., Itami Works, Itami, Japan. (*Ingots and small bars*)  
Sumitomo Metal Industries Ltd., Steel Tube Works, Amagasaki, Japan. (*Ingots, forgings, small bars, sections and seamless tubes*)  
Sumitomo Heavy Industries Ltd.  
Ehime Works, Niihama, Japan. (*Castings and forgings*)  
Tamashima Works, Kurashiki, Japan. (*Castings*)  
Tokushu Seikosho Co. Ltd., Kochi, Japan. (*Castings*)  
Toshin Steel Co., Ltd., Himeji Works, Himeji, Japan. (*Rolled sections and bars*)  
Toyo Kikai-Kinzoku Co., Ltd., Tsuchiyama Plant, Akashi, Japan. (*Small castings and small forgings*)  
Yamato Kogyo Co., Ltd., Himeji, Japan. (*Castings*)  
Yonago Steel Works, Ltd., Yonago, Japan. (*Castings*)

## Kristinehamn

Lesjöfors AB, Lesjöfors, Sweden. (*Ingots and billets*)

## La Spezia

Faggian, Acciaierie Elettriche Pio, Soc. per Azioni, La Spezia, Italy. (*Small castings*)

## Leghorn

Acciaierie di Piombino, Stabilimento di Portovecchio di Piombino, Italy. (*Ingots, blooms, sections and bars*)



**Lisbon**

"COMETNA" Companhia Metalurgica Nacional, S.A.R.L., Amadora, Portugal. (*Castings*)  
 Equimetal-Empresa Fabril de Equipamentos Metalicos S.A.R.L., Portugal. (*Castings*)  
 Fundicoes do Rossio de Abrantes S.A.R.L., Rossio de Abrantes, Portugal. (*Castings*)  
 Metalurgica Duarte Ferreira S.a.r.l., Tramagal, Portugal. (*Castings*)  
 Siderurgia Nacional, S.a.r.l., Seixal, Portugal. (*Sections and bars*)

**Lyons**

Aubert et Duval, Ets, Acieries des Ancizes, Les Ancizes, France. (*Ingots, rolled bars and forgings*)  
 d'Auxonne, Acieries et Fonderies, 21 Auxonne, France. (*Small castings*)  
 Creusot-Loire,  
 Branche Metallurgie, Groupe Transformation, Etablissement de l'Ondaine, 42 Firminy, France. (*Ingots, billets, blooms, bars, castings and forgings*)  
 Division Mécanique Entreprises, Usines de Saint-Chamond, 42 Saint-Chamond, France. (*Forgings*)  
 Division des Produits Laminés, d'Imphy-58, France. (*Ingots, forgings, bars and sections*)  
 Usine du Marais, 42 Saint-Etienne, France. (*Slabs and billets*)  
 Usines Schneider, Le Creusot, France. (*Ingots, forgings, castings, plates and sections*)  
 Furan, Acieries du, 42 Saint-Etienne, France. (*Electric steel castings*)  
 Geugnon, Forges de, 71 Geugnon, France. (*Rolling mill for plates*)  
 Marrel Frères, Société Anonyme des Etablissements, Usine des Etaings, near Rive-de-Giers 42, France. (*Ingots, plates and bars*)  
 Ugine-Aciars, Ugine, France. (*Ingots, billets, bars, sections, castings and forgings*)

**Madras**

Mysore, The, Iron & Steel Works, Ltd., Bhadravati. (*Bars, billets, blooms and sections*)

**Madrid**

Boetticher y Navarro S.A., Carretera de Andalucia KM9, Villaverde-Madrid, Spain. (*Small castings*)  
 Metalurgica Madrilenia S.A., Alcala de Henares, Madrid, Spain. (*Castings*)

**Malmö**

Kockums Jernverk, Kallinge, Sweden. (*Ingots and castings*)  
 Svedala-Arbra Aktiebolag, Svedala, Sweden. (*Castings*)

**Mannheim**

Dingler, Karcher & Cie., G.m.b.H., Saarländisches Stahlwerk, Worms/Rhein, Federal Republic of Germany. (*Castings*)

**Marseilles**

Creusot-Loire, Usine de Pamiers, Pamiers, France. (*Forgings*)  
 Feurs, Fonderies & Acieries Electriques de, Feurs (Loire), France. (*Small castings*)  
 Fonderies et Acieries de Provence, Marseilles, France. (*Castings*)  
 Pont à Mousson, S.A., Usine de Fumel, France. (*Castings, centrifugal cast pipes*)  
 Saut-du-Tarn, Société Nouvelle du, 81-Saint-Juéry, France. (*Castings*)  
 SOLMER, Fos-sur-Mer, Marseilles, France. (*Plates*)  
 Tamaris, Société des Ateliers et Fonderies des, 30 Tamaris, France. (*Castings*)  
 Ugine Aciars, Usine de Fos-sur-Mer, France. (*Bars*)

**Melbourne**

Davies & Baird Pty., Ltd., Newlands Road, Coburg, Melbourne, Australia. (*Castings*)  
 Steel Company of Australia, Pty., Ltd., Coburg, Melbourne, Australia. (*Castings*)  
 Vickers, Ruwolt, Pty., Ltd., Richmond, Melbourne, Australia. (*Steel castings and ingots*)

**Mexico City**

Altos Hornos de Mexico S.A., (A.H.M.S.A.), Monclova, Coah., Mexico. (*Plates*)  
 Fundidora Monterrey S.A., Monterrey, N.L., Mexico. (*Plates*)

**Milan**

Acciaieria di Rubiera S.p.A., Rubiera (Reggio Emilia), Italy. (*Ingots*)  
 Amsco Italiana S.p.A., Milan, Italy. (*Small castings*)  
 Breda Fucine, S.p.A., Sesto San Giovanni, Milan, Italy. (*Castings and forgings*)  
 Breda Siderurgica, S.p.A., Sesto San Giovanni, Milan, Italy. (*Ingots and sections*)  
 Brescia, Acciaieria e Turbificio di, S.p.A., Brescia, Italy. (*Ingots, sections, bars and castings*)  
 Carlo Tassara, Stabilimenti Electrosiderurgici S.p.A., Breno, Brescia, Italy. (*Ingots and small forgings*)  
 Ceretti, Pietro Maria, S.p.A., Ferriera dell' Ossola-Villadossola, Italy. (*Castings*)  
 Dalmine, S.p.A. Head Office: Milan, Italy.  
 Dalmine Costa Volpino, Bergamo. (*Seamless and welded tubes*)  
 Dalmine Works, Bergamo. (*Ingots and seamless tubes*)



## APPROVED MANUFACTURERS AND PROVING ESTABLISHMENTS

### Milan—continued

Falck, Acciaierie e Ferriere Lombarde. *Head Office & Works: Milan, Italy. (Weldless rolled or drawn tubes)*  
 Concordia Works, Sesto San Giovanni, Milan. *(Ingots and plates)*  
 Unione Works, Sesto San Giovanni, Milan. *(Ingots, sections, bars, forgings and castings)*  
 FOMAS—Forgiatura Moderna Acciai Speciali S.p.A., Osnago, (Como), Italy. *(Forgings)*  
 Fonderia Acciaio La Rapida, Olgiate Olona, Italy. *(Castings)*  
 Garavaglia S.A.S., Caronna Pentusella, Italy. *(Castings)*  
 "ITALSIDER" S.p.A. Stabilimento di Lovere, Italy. *(Sections, bars, castings and forgings)*  
 Luigi Giudici, Società per Azioni, Rescaldina, Milan, Italy. *(Small castings)*  
 S.I.S.M.A.—Società Industrie Siderurgiche Meccaniche & Affini, Villadossola (Novara), Italy. *(Rolled bars and rivets)*  
 Stramezzi, P., & C., Acciaieria e Ferriera di Crema, Crema, Italy. *(Ingots, bars, small sections and rivets)*  
 Tacca S.p.A., Acciaierie Fonderie, Gallarate, Italy. *(Small castings)*  
 Tosi, Franco, S.p.A., Legnano, Italy. *(Forgings and castings)*  
 Villa, Giovanni, S.p.A., Officine Meccaniche-Fucinati-Stampati, Milan, Italy. *(Forgings)*

### Mobile, Ala.

Republic Steel Corporation, Southern District, Gadsden, Ala., U.S.A. *(Plates)*  
 United States Steel Corporation, Fairfield Works, Ala., U.S.A. *(Rolling mills and forgings)*

### Montreal

Canadian Steel Foundries Division Hawker Siddeley Canada, Ltd., Longue Pointe, Montreal, P.Q., Canada. *(Castings)*  
 Crucible Steel Company of Canada, Ltd., Sorel, P.Q., Canada. *(Ingots and forgings)*  
 Dominion Steel & Coal Corporation Ltd., Montreal Works, 5870, St. Patrick Street, Montreal, P.Q., Canada. *(Angles, bars and rivets)*  
 Lynn Macleod Metallurgy, Ltd., Thetford Mines, P.Q., Canada. *(Castings)*  
 Manitoba Rolling Mills Division of Dominion Bridge Co., Ltd., Selkirk, Manitoba, Canada. *(Billets, bars and sections)*  
 Sorel Steel Foundries, Ltd., Sorel, P.Q., Canada. *(Castings)*  
 Steel Company of Canada, Hamilton, Ontario, Canada. *Works: Montreal. (Bars and angles, plates and billets)*  
 Unitcast Division of Midland-Ross of Canada Limited, Sherbrooke, Quebec, Canada. *(Castings)*

### Nagasaki

Kiyomoto Ironworks Co. Ltd., Takeo Works, Japan. *(Castings)*  
 Mitsubishi Heavy Industries Ltd., Nagasaki Shipyard and Engine Works, Nagasaki, Japan. *(Castings)*  
 Mitsui Miike Machinery Co. Ltd., Miike Works, Omuta, Japan. *(Castings)*  
 Nagasaki Metal Industries Association, Isahaya, Japan. *(Small forgings)*  
 Nippon Steel Corporation, Oita Works, Oita, Japan. *(Plates)*

### Nagoya

Aichi Steel Works, Ltd.  
 Chita Plant, Tokai, Japan. *(Ingots and bars)*  
 Kariya Plant, Kariya, Japan. *(Ingots and bars)*  
 Chuba Steel Plate Co. Ltd., Nakagawa Works, Nagoya, Japan. *(Ingots and plates)*  
 Daido Steel Co. Ltd.  
 Chita Plant, Tokai, Japan. *(Ingots, billets, bars and forgings)*  
 Hoshizaki Plant, Nagoya, Japan. *(Ingots and bars)*  
 Tsukiji Plant, Nagoya, Japan. *(Ingots, forgings and castings)*  
 Go Iron Works Ltd., Tarui Works, Tarui, Japan. *(Small castings)*  
 Howa Machinery Ltd., Inazawa Plant, Inazawa, Japan. *(Castings)*  
 Kawasaki Steel Corporation, Chita Works, Handa, Japan. *(Ingots, castings and seamless tubes and pipes)*  
 Kinka Kikai Co. Ltd., Gifu, Japan. *(Castings)*  
 Nakayama Steel Works Ltd., Nagoya Works, Aichi Prefecture, Japan. *(Slabs)*  
 Nippon Sharyo Seizo Kaisha Ltd., Nagoya, Japan. *(Castings)*  
 Nippon Steel Corporation, Nagoya Works, Tokai, Japan. *(Ingots, plates and electric resistance welded tubes)*  
 Tokai Special Steel Co. Ltd., Tokai, Japan. *(Ingots)*  
 Topy Industries Ltd., Toyohashi Works, Toyohashi, Japan. *(Ingots, sections and flat bars)*  
 Wasino Machine Co. Ltd.  
 Imamura Plant, Anjo, Japan. *(Castings)*  
 Komaki Plant, Komaki, Japan. *(Small castings)*

### Nancy

#### WORKS IN FRANCE

Acières et Fonderies de l'Est, France,  
 Usine de Colombier-Fontaine. *(Small castings)*  
 Usine de Sainte Suzanne. *(Castings)*  
 Cockerill-Ougrée-Providence, Rehon Works, Rehon, France. *(Strip)*  
 Ferry Capitain S.A.R.L., Usines de Bussy-Joinville, France. *(Electric steel castings)*



**Nancy—continued**

Meuse, Société Métallurgique de la, Forges et Aciéries de Stenay, 55 Stenay, France. (*Castings*)

SACILOR, France,

Etablissement d'Hagondange, 57 Hagondange. (*Blooms, billets, bars and sections*)

Etablissement d'Orne-Amont, 54 Homecourt. (*Ingots, blooms, billets, narrow plates and universal flats*)

Usine de Gandrange, 57 Gandrange. (*Ingots, blooms, billets and flat bars*)

Usine de Knutange, 57 Hayange. (*Sections*)

Usine de Rombas, 57 Rombas. (*Ingots, blooms, billets, bars and sections*)

Usine de Saint-Jacques, 57 Hayange. (*Rolling mill for sections*)

Société des Aciers Fins de l'Est, 57 Hagondange, France. (*Ingots, blooms, billets, bars, plates and sheets*)

Société Lorraine de Laminage Continu, Sollac, BP11, 57 Florange, France. (*Ingots, slabs and plates*)

Société Nouvelle des Aciéries de Pompey, 54 Pompey, France. (*Ingots, blooms, billets, plates, angles and round bars*)

Union Sidérurgique du Nord et de l'Est de la France, "USINOR",

GROUPE C, Usine de Longwy, 54 Longwy, France

Section Mont Saint Martin (*Sections and plates*)

Section Senelle. (*Ingots, blooms, bars and sections*)

Usine de Thionville, 57 Thionville, France. (*Forgings and castings*)

**WORKS IN LUXEMBOURG**

"ARBED", Aciéries réunies de Burbach-Eich-Dudelange,

Division de Differdange, Differdange, Luxembourg. (*Sections and bars*)

Division de Dommeldange, Dommeldange, Luxembourg. (*Ingots, forgings and castings*)

Division d'Esch-Belval-Esch-sur-Allzette, Luxembourg. (*Ingots, blooms, billets, bars, angle bars and sections*)

Division d'Esch-Schifflange, Esch-sur-Allzette, Luxembourg. (*Ingots, bars and sections*)

Minèrie et Métallurgique de Rodange S.A., Rodange, Luxembourg. (*Sections*)

Wurth, Société Anonyme des Anciens Etablissement Paul, Luxembourg. (*Castings*)

**Nantes**

Acieries de Bordeaux, Pessac-Gironde, France. (*Castings*)

Sambre et Meuse, Société Anonyme des Usines & Aciéries de, Usines de Saint Brieuc-22, France. (*Small castings*)

**Naples**

Acciaierie e Tubificio Meridionali, S.p.A., Bari, Italy. (*Castings and seamless tubes*)

Fucine Meridionali, S.p.A., Bari, Italy. (*Castings and forgings*)

"ITALSIDER" Alti Forni e Acciaierie Riunite Ilva e Cornigliano S.p.A., Italy.

Stabilimento di Taranto. (*Ingots, slabs and plates*)

"ITALSIDER" S.p.A., Centro Siderurgico di Bagnoli, Naples, Italy. (*Ingots, sections and bars*)

S.I.T.-S.p.A., Stampaggio Industriale Terni, Terni, Italy. (*Small forgings*)

"Terni" Società per l'Industria e l'Elettricità, Italy.

Works: Terni. (*Ingots, forgings, castings and plates*)

Walworth Aloyco and Grove International S.p.A., Stabilimento di Napoli, Naples, Italy. (*Castings*)

**Newcastle, N.S.W.**

Broken Hill Proprietary Co., Ltd., Iron and Steel Works, Newcastle, N.S.W., Australia. (*Ingots, billets, plates, sections, strip and castings*)

Commonwealth Steel Co., Ltd., Waratah, Newcastle, N.S.W., Australia. (*Castings, forgings, ingots and bars*)

**Newport News, Va.**

Newport News Shipbuilding & Dry Dock Co., Newport News, Va., U.S.A. (*Castings and forgings*)

**Odense**

Jernstøberiet Kongeaa A/S, Vamdrup, Denmark. (*Castings*)

Varde Staalvaerk, Varde, Denmark. (*Ingots and castings*)

**Osaka**

Chubu Steel Tube Co., Ltd., Osaka, Japan. (*Seamless tubes*)

Daitetsu Steel Industrial Co., Ltd., Osaka, Japan. (*Ingots and sections*)

Endo Co. Ltd., Osaka, Japan. (*Forgings*)

Hitachi Shipbuilding & Engineering Co., Ltd., Chikko Shipyard, Osaka, Japan. (*Ingots, castings and forgings*)

Izuo Chukosho Co., Ltd., Osaka, Japan. (*Castings*)

J.M.C. Engineering Co., Ltd., Takaoka, Japan. (*Castings*)

Kansai Steel Corp., Sakai, Japan. (*Ingots, bars and sections*)

Kokoku Steel Casting Co., Ltd., Osaka, Japan. (*Castings*)

Komatsu, Ltd.,

Awazu Plant, Komatsu, Japan. (*Castings*)

Osaka Plant, Hirakata, Japan. (*Castings*)

Kubota Ltd., Hirakata Plant, Hirakata, Japan. (*Castings*)

Kureha Seiko Co. Ltd., Osaka, Japan. (*Castings*)

Kurimoto Iron Works, Ltd., Kagaya Factory, Osaka, Japan. (*Castings*)



## APPROVED MANUFACTURERS AND PROVING ESTABLISHMENTS

### Osaka—continued

Mackewa Electric Steel Castings Co., Osaka, Japan. (*Castings*)  
 Mitsui Shipbuilding & Engineering Co., Ltd., Fujinata Works, Osaka, Japan. (*Forgings*)  
 Mitsumoto Valve Manufacturing Co. Ltd., Fujiidera, Osaka, Japan. (*Small forgings and small castings*)  
 Miyazaki Iron Works Co., Ltd., Osaka, Japan. (*Small forgings*)  
 Nakayama Steel Works Ltd., Funamachi Works, Osaka, Japan. (*Ingots and plates*)  
 Nippon Steel Corp., Sakai Works, Sakai, Japan. (*Ingots, sections and thin plates*)  
 Nippon Steel Foundry Co., Ltd., Osaka, Japan. (*Castings*)  
 Nippon Yakin Kogyo Co., Ltd., Kanazawa Works, Kanazawa, Japan. (*Castings in special steels*)  
 Nishiyodo Steel Making Co. Ltd., Osaka, Japan. (*Castings*)  
 Osaka Chain & Machinery Co. Ltd., Kaizuka Works, Kaizuka, Osaka, Japan. (*Small castings*)  
 Osaka Steel Castings Co., Ltd., Osaka, Japan. (*Small castings*)  
 Pacific Metals Ltd., Toyama Factory, Toyama, Japan. (*Ingots and forgings*)  
 Rikimi Cast Steel Co. Ltd., Higashi-Osaka, Japan. (*Small castings*)  
 Seo Koatsu Kogyo Co., Ltd., Osaka, Japan. (*Small forgings*)  
 Showa Steel Tube Works, Ltd., Sakai, Japan. (*Seamless tubes*)  
 Sumitomo Metal Industries, Ltd.,  
     Osaka Steel Works, Osaka, Japan. (*Castings, forgings and bars*)  
     Steel Tube Works, Amagasaki Kainan Plant, Kainan, Japan. (*Seamless tubes*)  
     Wakayama Steel Works, Wakayama, Japan. (*Ingots, plates, seamless tubes and electric resistance welded tubes*)  
 Takada Steel Works, Ltd., Yamato-Takada, Japan. (*Castings*)  
 Teikoku Kokan Seizoshu, Osaka, Japan. (*Seamless tubes*)  
 Teikoku Steel Casting Co., Ltd., Osaka, Japan. (*Castings*)  
 Yamato Steel Works, Ltd., Osaka, Japan. (*Ingots, sections and plates*)  
 Yamazaki Machinery Mfg. Co. Ltd., Shiga Prefecture, Japan. (*Small forgings*)

### Oslo

Drammens Jernstoberi & Mek-Verksted, A/S, Drammen, Norway. (*Small castings*)  
 Elkem-Spigerverket A/S, Christiania Spigerverk, Oslo, Norway. (*Ingots and bars, also rivet bars*)  
 Norsk Jernverk, A/S, Mo-i-Rana, Norway. (*Electric steel ingots, billets, sections and bars*)  
 Strommen Staal A/S, Norway.  
     Works: Raufoss. (*Castings*)  
     Strømmen. (*Castings*)

### Paris

Gennevilliers, Aciéries de, Gennevilliers (Seine), France. (*Castings*)  
 Paris-Seine, Fonderies et Aciéries, Usine de la Folie, Avenue de Bobigny, Noisy-le-Sec. (Seine), France. (*Castings*)

### Philadelphia, Pa.

Atlantic Steel Castings Co., The, Chester, Pa., U.S.A. (*Castings*)  
 Bethlehem Steel Corporation, Bethlehem, Pa., U.S.A. (*Ingots, forgings, bars and sections*)  
     Lebanon, Pa., U.S.A. (*Rolling mills for bars and rivets*)  
     Steelton, Pa., U.S.A. (*Castings*)  
 Birdsboro Corporation, Birdsboro, Pa., U.S.A. (*Castings*)  
 Empire Steel Castings Inc., Reading Pa., U.S.A. (*Castings*)  
 Lebanon Steel Foundry, Lebanon, Pa., U.S.A. (*Castings*)  
 Lukens Steel Company, Coatesville, Pa., U.S.A. (*Plates*)  
 Midvale-Heppenstall Company, Nicetown, Philadelphia, Pa., U.S.A. (*Forgings*)  
 Pennsylvania Steel Foundry and Machine Company, Hamburg, Pa., U.S.A. (*Castings*)  
 Phoenix Steel Corporation.  
     Works: Claymont, Delaware, U.S.A. (*Plates*)  
     Works: Structural Division, Phoenixville, Pa., U.S.A. (*Sections, bars and rotary forged seamless tubes*)  
 Quaker Alloy Casting Co., Myerstown, Pa., U.S.A. (*Castings*)  
 Standard Steel Division of Titanium Metal Corp. of America, Burnham, Pa., U.S.A. (*Forgings*)  
 Tube Turns, Philadelphia Plant, Division of Chemetron Corporation, Tacony, Philadelphia, Pa., U.S.A. (*Forgings*)  
 United States Steel Corporation, Fairless Works, Fairless Hills, Pa., U.S.A. (*Thin plates, bars and sections*)  
 Wood, Alan, Steel Company, Conshohocken, Pa., U.S.A. (*Blooms, billets and plates*)

### Piraeus

Viomichania Chalyvon Ltd., Athens, Greece. (*Castings*)

### Poona

Bharat Forge Company Ltd., Mundhwa, Poona, India. (*Forgings*)

### Port Elizabeth

Ferrovorm Ltd., Port Elizabeth, Foundry Division, South Africa. (*Small castings*)

### Port Kembla

Australian Iron & Steel Pty., Ltd., Port Kembla, N.S.W., Australia. (*Plates, bars, sections and forgings*)



**Rijeka**

Titovi Zavodi Litostroj, Ljubljana, Yugoslavia. *(Castings)*

Tvornica Dizalica I Ljevaonica "Vulkan" Rijeka 11, Yugoslavia. *(Castings)*

Združeno Podjetje Slovenske Željezarne, Željezarna Ravne, Ravne na Koroškem, Yugoslavia. *(Castings, forgings, billets and bars)*

Zeljezara Sisak, Sisak Predgradje, Yugoslavia. *(Seamless tubes)*

**Rio de Janeiro**

Companhia Ferro e Aço de Vitoria, Vitoria, State of Espirito Santo, Brazil. *(Rolling mill for bars and sections)*

Companhia Siderurgica Hime, Usina de Neves São Gonçalo, Estado do Rio de Janeiro, Brazil. *(Ingots, sections and bars)*

Companhia Siderurgica Nacional, Usina Presidente Vargas, Volta Redonda, Estado do Rio de Janeiro, Brazil. *(Plates and sections)*

Usinas Siderurgicas de Minas Gerais S.A., Belo Horizonte, Estado de Minas Gerais, Brazil.

*Works:* Ipatinga, Estado de Minas Gerais. *(Ingots, slabs and plates)*

**Rotterdam**

Bakker N.V., Machinefabriek-Staalgieterij, Ridderkerk, Holland. *(Ingots and castings)*

Oranje Nassau Staal B.V., Heerlen, Holland. *(Small castings)*

Rotterdamsche Droogdok Maatschappij, Rotterdam, Holland. *(Ingots, forgings and small castings)*

**Rouen**

Manoir-Pompey, Acieries du, 27 Pitres, France. *(Castings)*

Société Métallurgique de Normandie, Mondeville, France *(Ingots, blooms, billets and bars)*

**Saarbrücken**

A.G. der Dillinger Hüttenwerke, Dillingen/Saar. *(Ingots and plates)*

Neunkircher Eisenwerk A.G., Neunkirchen/Saar. Neunkirchen Works. *(Ingots, bars and sections)*  
Homburg Works. *(Ingots and seamless tubes)*

Pohlig-Heckel-Bleichert, Vereinigte Maschinenfabriken A.G., Abt. Stahlformgiesserei, Werk Heckel, Rohrbach/Saar. *(Castings)*

Röhrenwerke Bous G.m.b.H., Bous/Saar. *(Seamless tubes)*

Stahlwerke Röchling-Burbach G.m.b.H.

*Works:* Burbach. *(Ingots, billets and sections)*

*Works:* Völklingen. *(Castings, ingots, billets, bars and forgings)*

**San Francisco, Cal.**

De Laval Turbine Inc., Engine & Compressor Division, Oakland, Cal., U.S.A. *(Castings)*

Pacific States Steel Corporation, Union City, Cal., U.S.A. *(Ingots, sections and bars)*

Pacific Steel Castings Co., Berkeley, Cal., U.S.A. *(Castings)*

**Santos**

Companhia Siderurgica Paulista, Cosipa, Cubatao, São Paulo, Brazil. *(Ingots and plates)*

**São Paulo**

Acos Villares S.A., São Caetano do Sul, São Paulo, Brazil. *(Castings, forgings, billets and bars)*

**Sasebo**

Osaka Steel Tube Co. Ltd., Sasebo Works, Sasebo, Japan. *(Seamless tubes)*

Sasebo Heavy Industries Co. Ltd., Sasebo Shipyard, Sasebo, Japan. *(Forgings)*

Sasebo Seiko Co. Ltd., Sasebo, Japan. *(Ingots and castings)*

**Seattle, Wash.**

Bendix Skagit Corporation, Sedro Woolley, Washington, U.S.A. *(Castings)*

Bethlehem Steel Co., Seattle, Wash., U.S.A. *(Sections, bars and narrow flats)*

Jorgensen, Earle M. Co., Forge Division, Seattle, Wash., U.S.A. *(Ingots and forgings)*

Oregon Steel Mills, Division of Gilmore Steel Corporation, 5200 N.W. Front Ave., Portland, Oregon 97210, U.S.A. *(Rolling mill for plates and sections)*

Washington Iron Works, Seattle, Wash., U.S.A. *(Castings)*

**Seoul**

Hyundai International Inc., Gunpo Plant, Seoul, Korea. *(Castings)*

Kangwon Industrial Co., Ltd., Pohang Works, Korea. *(Castings)*

Korea Heavy Machinery Industries Ltd. (KOHEMA), Seoul, Korea. *(Castings)*

**Shimonoseki**

Hitachi Metals Ltd., Tobata Works, Kitakyushu, Japan. *(Castings)*

Japan Casting & Forging Corporation, Kitakyushu, Japan. *(Forgings and castings)*

Kobukuro Iron Works Co. Ltd., Iizuka Works, Iizuka, Japan. *(Castings)*

Maekawa Electric Steel Castings Co., Ltd., Tobata Factory, Kitakyushu, Japan. *(Castings)*



# APPROVED MANUFACTURERS AND PROVING ESTABLISHMENTS

## Shimonoseki—continued

### Nippon Steel Corporation.

Plant and Machinery Division, Kitakyushu, Japan.  
(*Castings and forgings*)

Yawata Works, Kitakyushu, Japan. (*Plates, sections and ingots*)

Nishinoh Tanko Co. Ltd., Fukuoka Prefecture, Japan.  
(*Small forgings*)

Okano Valve Manufacturing Co., Yukubashi Foundry, Yukubashi, Japan. (*Small castings and small forgings*)

Ozuki Seikosho Ltd., Shimonoseki, Japan. (*Castings*)

Rasa Industries Ltd., Hainuzuka Works, Chikugo, Japan.  
(*Castings*)

Seibu Kogyo Co. Ltd., Yawata Steel Casting Works, Kitakyushu, Japan. (*Castings*)

Sumitomo Metal Industries, Ltd., Kokura Steel Works, Kitakyushu, Japan. (*Ingots, billets, bars and sections*)

Ube Industries, Ltd., Ube Machinery Works, Ube, Japan. (*Ingots, forgings and castings*)

Wakamatsu Sharyo Co. Ltd., Kitakyushu, Japan.  
(*Small castings*)

## Singapore

Bradken Malaysia Sdn. Berhad, Lahat Papn Road, Ipoh, Perak, Malaysia. (*Castings*)

National Iron & Steel Mills Ltd., Jalan Besi Baja, Jurong Industrial Estate, Singapore. (*Small sections and bars*)

United Engineers (Singapore) Pte. Ltd., Kampong Bahru Foundry, Singapore. (*Castings*)

## Split

Rudarsko-Metalurski Kombinat-Zenica, Zeljezara Zenica, Zenica, Yugoslavia. (*Billets, bars, sections and forgings*)

Rudnici i Zelezara Smederevo, Smederevo, Yugoslavia.  
(*Small castings*)

Rudnici I Zelezarnica, "Skopje", Skopje, Yugoslavia.  
(*Plates*)

Združeno Podjette Slovenske Zelezarne, Zelezarna Jesenice, Jesenice, Yugoslavia. (*Plates, bars, sections and castings*)

Zeljezara "Boris Kidric", Niksic, Yugoslavia. (*Plates and castings*)

## Stockholm

Aktiebolaget Jarnforadling, Halleforsnas, Sweden. (*Small castings*)

Avesta Jernverks Aktiebolag, Avesta, Sweden. (*Plates, sections and castings*)

Boxholms A/B., Boxholm, Sweden. (*Ingots, rolled slabs, blooms, billets, sections and bars*)

Bulten-Kanthal AB. Kanthal-Divisionen, Hallstahammar, Sweden. (*Ingots, billets, bars and castings*)

## Stockholm—continued

Fagersta Aktiebolag, Fagersta, Sweden (Brukskoncernen).

*Works:* Fagersta. (*Blooms, billets, rolled bars and electric resistance welded tubes*)

*Works:* Forsbacka. (*Blooms, billets, forged and rolled bars*)

*Works:* Osterbyverken, Osterbybruk. (*Castings, forgings and rolling mill for bars*)

Gränges Stål, Oxelösunds Järnverk, Oxelösund, Sweden.  
(*Ingots, rolled slabs and plates*)

Hallstahammar Aktiebolag, Hallstahammar, Sweden.  
(*Bars*)

Hults Bruk A.B., Aby, Sweden. (*Castings*)

Kohlswa Jernverks Aktiebolag, Sweden. (*Ingots, forgings and castings*)

Norrbottnens Järnverk Aktiebolag, Lulea, Sweden.  
(*Ingots, slabs, blooms and billets, bars and sections*)

SKF, Stål Hofors Bruk, Hofors, Sweden. (*Billets, bars, forgings and thick walled tubes*)

Saab-Scania, Nordarmaturdivisionen, Linköping, Sweden. (*Castings*)

Sandvik Aktiebolag, Sandviken, Sweden. (*Ingots, forgings and tubes*)

Smedjebackens Valsverks Aktiebolag, Smedjebacken, Sweden. (*Bars, sections and ingots for re-rolling*)

Stora Kopparbergs Bergslags A/B Specialstålverken, Vikmanshyttan, Sweden. (*Forgings, bars and sections*)

Stora Kopparbergs Bergslags Aktiebolag, Falun, Sweden.  
*Works:* Domnarfvet. (*Ingots, sections and plates*)

*Works:* Söderfors. (*Forgings, bars and sections*)

Surahammars Bruks Aktiebolag, Surahammar, Sweden.  
(*Plates, forgings and castings*)

Svenska Kullagerfabriken, Aktiebolaget, Katrineholm, Sweden. (*Castings*)

## Stuttgart

Streicher, M., Asperg/Wurtt, near Stuttgart, Federal Republic of Germany. (*Castings*)

Voith, J. M., G.m.b.H., Heidenheim, Federal Republic of Germany. (*Steel castings*)

## Sydney, N.S.W.

Bradford, Kendall, Ltd., Alexandria, Sydney, N.S.W., Australia. (*Ingots and castings*)

Commonwealth Steel Co., Ltd., Lidcombe, Sydney, Australia. (*Castings*)

## Taipei

Tang Eng Iron Works Co., Ltd., Chung Hsin Alloy Steel Plant, Kaohsiung, Taiwan. (*Forgings*)



**Toronto, Ontario**

Algoma Steel Corporation, Ltd., Sault Ste. Marie, Ontario, Canada. (*Plates, sections and bars*)  
 Atlas Steels Company, Welland, Ontario, Canada. (*Ingots and bars*)  
 Black Clawson-Kennedy, Owen Sound, Ontario, Canada. (*Castings*)  
 Burlington Steel Company, Division of Slater Steel Industries, Ltd., Hamilton, Ontario, Canada. (*Small sections and bars*)  
 Canada Forgings Ltd., Welland, Ontario, Canada. (*Forgings*)  
 Dominion Foundries & Steel, Ltd., Hamilton, Ontario, Canada. (*Ingots, plates and castings*)  
 Interprovincial Steel and Pipe Corporation Ltd., Regina, Saskatchewan, Canada. (*Plates*)  
 Steel Company of Canada, Hamilton, Ontario, Canada. (*Bars, angles, plates and billets*)  
 Welmet Industries, Ltd., Welland, Ontario, Canada. (*Castings*)

**Trieste**

Acciaieria Fonderia Cividale S.p.A., Cividale (Udine), Italy. (*Ingots*)  
 Bertoli S.p.A., Officine Fratelli Bertoli fu Rodolfo, Udine, Italy. (*Castings, forgings, bars and sections*)  
 Orion S.p.A., Porto Industriale, Trieste, Italy. (*Forgings and castings*)  
 S.A.F.A.U. Ferriere Acciaierie di Udine, Udine, Italy. (*Ingots, forgings, blooms, bars and sections*)  
 Safog, S.A., Fonderie Officine di Gorizia, Gorizia, Italy. (*Castings*)

**Turku/Åbo**

Ovako Oy, Äminneförs Steel Works, Äminneförs, Finland. (*Ingots, billets, bars and sections*)  
 Oy Fiskars Ab Salon Konepaja, Salo, Finland. (*Small castings*)  
 Oy Koverhar Ab, Lappvik, Finland. (*Billets*)  
 Oy W. Rosenlew, Ab, Porin Konepaja, Pori, Finland. (*Small castings*)

**Valencia**

Españoles Astilleros S.A., Factoria de Manises, Valencia, Spain. (*Castings*)  
 Vizcaya, Altos Hornos de, S.A., Fabrica de Sagunto, Sagunto, Spain. (*Ingots, plates, bars and sections*)

**Valenciennes**

Blanc-Misseron, Société Française des Aciéries de, 59 Quievrechain, France. (*Ingots and castings*)  
 Chiers, Société des Hauts-Fourneaux de la, Forges de Vireux Molhain, 8 Vireux, France. (*Bars and sections*)  
 Cockerill-Ougree-Providence, Groupe D, Usines d'Hautmont 59, France. (*Ingots and sections*)

**Valenciennes—continued**

Dembiermont & Cie., Maurice, 59 Hautmont, France. (*Forgings*)  
 Fives-Lille-Cail, Société de.  
     Usine de Denain, 59 Denain, France. (*Castings, ingots, forgings, blooms, bars and sheets*)  
 Fonderies Grandry S.A., 8 Mohon, France. (*Castings*)  
 Haine-St.-Pierre et Lesquin, Aciéries de, Société Anonyme, 59 Lesquin-lez-Lille, France. (*Castings*)  
 Maubeuge, Société Anonyme de la Fabrique de Fer de, 59 Louvroil, France. (*Ingots*)  
 Paris & d'Outreau, Aciéries de, Usines d'Hirson, 2 Hirson, France. (*Castings*)  
 Porter, H. K., (France), Aciéries Division Marpent, 59 Marpent, France. (*Ingots for forgings and castings*)  
 Sambre et Meuse, Société Anonyme des Usines et Aciéries de, Usines de Feignies, 59 Feignies, France. (*Castings*)  
 Union Siderurgique du Nord et de l'Est de la France, "USINOR"  
     GROUPE A.  
         Usines de Denain, 59 Denain, France. (*Ingots, thin plates and sections*)  
     GROUPE B.  
         Usines de Valenciennes, 59 Valenciennes, France. (*Ingots, forgings, blooms, bars and sections*)  
 VALLOUREC,  
     Usine d'Anzin, 59 Anzin, France. (*Seamless tubes*)  
     Usine d'Aulnoye, 59 Aulnoye, France. (*Weldless rolled or drawn tubes*)

**Valparaiso**

Pacifico, Compania de Acero del, S.A., Talcahuano, Chile. (*Ingots, plates, bars and sections*)

**Vancouver, B.C.**

A.I. Steel & Iron Foundry (Vancouver) Ltd., Vancouver, B.C., Canada. (*Small castings*)  
 C.A.E. Machinery Ltd., Vancouver, B.C., Canada. (*Small castings*)  
 Cominco Ltd., Trail, B.C., Canada. (*Castings*)  
 Esco Ltd., Port Coquitlam, B.C., Canada. (*Castings*)  
 Letson & Burpee, Ltd., Surrey, British Columbia, Canada. (*Small castings*)  
 Mainland Foundry & Eng. Ltd., Vancouver, B.C., Canada. (*Castings*)  
 Victoria Machinery Depot Co., Ltd., Victoria, B.C., Canada. (*Castings*)  
 Western Canada Steel Ltd., (Vancouver Rolling Mills Ltd.) Vancouver, B.C., Canada. (*Sections and bars*)

**Venice (Mestre)**

A.V.E.G. S.p.A. (Acciaierie Valbruna Ernesto Gresele), Vicenza, Italy. (*Castings, bars, sections and forgings*)  
 Bolzano, S.p.A. Acciaierie di, Bolzano, Italy. (*Ingots, billets, bars and forgings*)



## APPROVED MANUFACTURERS AND PROVING ESTABLISHMENTS

### Venice (Mestre)—continued

Flag S.p.A., Marcon (Mestre), Italy. (*Small castings*)  
 "ITALSIDER" Alti Forni e Acciaierie Riunite Ilva e Cornigliano S.p.A., Stabilimento di Marghera, Italy. (*Rolling mills for small sections and bars*)  
 S.A.F.A.S.—Società Azionaria Fonderia Acciai Speciali, Tavernelle di Altavilla, Vicentina, (Vicenza), Italy. (*Castings*)

### Vereeniging

Dunswart Iron & Steel Works, Ltd., Benoni, S. Africa. (*Castings, ingots, billets, and small sections*)  
 Highveld Steel & Vanadium Corp. Ltd., Witbank, South Africa. (*Sections and flats*)  
 Scaw Metals, Ltd., Union Junction, Transvaal, S. Africa. (*Rivet bars, small rolled sections and castings*)  
 South African Iron & Steel Industrial Corporation, Ltd. "Isacor" Works, Pretoria, Transvaal, S. Africa. (*Ingots, billets, bars, sections and forgings*)  
 "Isacor" Works, Vanderbijlpark, Transvaal, S. Africa. (*Ingots, billets, slabs and plates*)  
 Union Steel Corporation of South Africa, Ltd., "Usco" Steel Works, Vereeniging, Transvaal, S. Africa. (*Ingots, billets, small sections, castings and rivet bars*)  
 Vecor Heavy Engineering, Ltd., Vanderbijlpark, Transvaal, S. Africa. (*Castings*)

### Vienna

#### WORKS IN AUSTRIA

Böhler, Gebr., & Co., Aktiengesellschaft, Vienna.  
*Works:* Bohlerwerk, Low Austria. (*Small forgings*)  
*Works:* Bruckbach, Low Austria. (*Rolling mills for sections and bars*)  
*Works:* Kapfenberg, Styria. (*Ingots, castings, forgings, bars and plates*)  
 Eisenwerk Breitenfeld Ges.m.b.H., Mitterdorf/Murztal, Austria. (*Forgings*)  
 Hubner-Vamag, Vereinigte Armaturenfabriken, Aktiengesellschaft, Vienna, Austria. (*Castings*)  
 Klinger, Rich., Aktiengesellschaft, Gumpoldskirchen, near Vienna. (*Small castings*)  
 Schoeller-Bleckmann Stahlwerke A.G., Vienna.  
*Works:* Muerzzuschlag-Hoenigsberg, Styria. (*Bars*)  
*Works:* Ternitz, Low Austria. (*Castings, forgings and bars*)  
 Steirische Gusstahlwerke, A.G., Vienna.  
*Works:* Judenburg, Styria. (*Forgings and bars*)  
 Vereinigte Österreichische Eisen-und-Stahlwerke-Alpine Montan Aktiengesellschaft Linz.  
*Works:* Donauwitz, Styria. (*Sections, strip and bars*)  
*Works:* Kindberg-Krieglach, Styria. (*Rolling mills for small sections, bars and strip*)  
*Works:* Liezen, Styria. (*Ingots for forgings, castings*)  
*Works:* Linz a.d. Donau, Upper Austria. (*Plates, forgings and castings*)  
*Works:* Traisen, Low Austria. (*Castings*)

### Vienna—continued

Waagner-Biro Aktiengesellschaft, Werk Wien, Austria. (*Castings*)

#### WORKS IN CZECHOSLOVAKIA

Nová huť Klementa Gottwalda, národní podnik (New Metallurgical Works of Klement Gottwald, National Corporation), Ostrava-Kunčice. (*Ingots*)  
 Škoda, národní podnik (Skoda National Corporation), České Budějovice Works. (*Castings*)  
 Plzeň Works. (*Castings and forgings*)  
 Slatina národní podnik, (Slatina National Corporation), Brno. (*Castings*)  
 Svermore Železiarne, národný podnik (Sverma's Iron Works, National Corporation), Podbrezová. (*Ingots and plates*)  
 Třinecké železářny velké Řijnové socialistické revoluce, národní podnik (Třinec Iron Works Great Socialistic October Revolution National Corporation), Třinec. (*Ingots, sections, bars and castings*)  
 Vitkovické Železářny a Strojirny Klementa Gottwalda, národní podnik (The Vitkovice Steel and Engineering Works of Klement Gottwald, National Corporation), Ostrava 10. (*Castings, forgings, plates, sections, bars and seamless tubes*)  
 Východoslovenské Železiarne, národný podnik, (East Slovak Steelworks, National Corporation), Košice. (*Slabs*)  
 Železářny Bila Cerkev, národní podnik, (Steelworks "Bila Cerkev" National Corporation)  
*Works:* Chomutov. (*Seamless tubes*)  
*Works:* Hrádek u Rokycan. (*Ingots and bars*)  
 Železářny a drátovny Bohumin, národní podnik (Iron Works & Wire Works Bohumin, National Corporation), Bohumin, Czechoslovakia. (*Small sections and bars*)

#### WORKS IN HUNGARY

Ganz-Mavag Mozdony Vagon es Gepgyar, Budapest. (*Castings and forgings*)  
 K.G.M. Altalanos Gepipari Igazgatóság, Budapest.  
*Works:* Őntondei Vallalat Kobanyai Vas-es Acelontodeje, Budapest. (*Castings*)  
 K.G.M. Jarmuipari Igazgatóság, Budapest.  
*Works:* Magyar Vagon-és Gépgyár, Győr. (*Castings*)  
 Magyar Vas-és Acelipari Egyesülés, Budapest,  
*Works:* Lenin Kohászati Művek, Miskolc-Diósgyőr. (*Ingots, slabs, sections, bars, castings and forgings*)  
*Works:* Dunai Vasnü, Dunaujváros. (*Ingots, slabs and plates*)  
*Works:* Dunai Vasmü, Lőrinci Hengerműve, Budapest. (*Rolling mill for plates*)  
*Works:* Ozdi Kohászati, Uzemek, Ozd. (*Ingots, slabs, plates, sections and bars*)

### Vigo

Aceros de Galicia, Vigo, Spain. (*Castings*)



**Whyalla**

Broken Hill Proprietary Co., Ltd., Iron and Steel Works, Whyalla, S. Australia. (*Ingots, castings, bars and sections*)

**Winterthur**

Eisen-und Stahlwerke Oehler & Co. A.G., Aarau, Switzerland. (*Castings*)

Fischer, George, Ltd., Schaffhausen, Switzerland. (*Castings*)

Fonderie de Fer et d'Aciers, Bienne-Biel, Switzerland. (*Castings*)

Sulzer Bros., Ltd., Winterthur, Switzerland. (*Castings and forgings*)

Von Roll A.-G., Gerlafingen, Switzerland. (*Ingots, round bars and forgings*)

**Yokohama**

Akimoku Steel Casting Co., Ltd., Nashiro-City, Japan. (*Castings*)

Akita Kinzoku Kogyo Co. Ltd., Akita, Japan. (*Castings*)

Ando Iron Works Co., Ltd., Tokyo, Japan. (*Small forgings*)

Daido Steel Co., Ltd., Shibukawa Works, Shibukawa, Japan. (*Ingots, small forgings and bars*)

Date Seiko Co. Ltd., Fukushima Prefecture, Japan. (*Castings*)

Fukushima Seiko Co., Ltd., Fukushima, Japan. (*Castings*)

Funabashi Steel Works Ltd., Funabashi, Japan. (*Ingots and flat bars*)

Hakodate Dock Co., Ltd., Hakodate Shipyard, Hakodate, Japan. (*Small castings and forgings*)

Haneda Pipe Works Co., Ltd., Tokyo, Japan. (*Seamless and cold finished electric resistance welded tubes*)

Hatakeyama Iron Works Co. Ltd., Higashi Komatsugawa Works, Tokyo, Japan. (*Small forgings*)

Hitachi Ltd., Japan.

Hitachi Works, Hitachi. (*Castings*)

Katsuta Works, Katsuta. (*Ingots, forgings and castings*)

Hokuriku Kogyo Co. Ltd., Sanjo Plant, Sanjo, Japan. (*Small forgings*)

Ishikawajima-Harima Heavy Industries Co. Ltd., Tokyo Works, Tokyo, Japan. (*Ingots, forgings and castings*)

Japan Casting Co. Ltd., Kawasaki, Japan. (*Castings*)

Japan Special Steel Co., Ltd., Tokyo, Japan. (*Ingots, forgings, blooms, billets and bars*)

Japan Steel Works Ltd., Muroran Works, Muroran, Japan. (*Ingots, forgings, castings and plates*)

Joban Machinery Co. Ltd., Uchigo Factory, Iwaki, Japan. (*Castings*)

Jonan Iron Works Co. Ltd., Haneda Works, Tokyo, Japan. (*Small forgings*)

Keagegawa Endo Iron Works Co., Ltd., Keagegawa, Japan. (*Forgings*)

**Yokohama—continued**

Kanda Sangyo Co., Ltd., Kawasaki, Japan. (*Small forgings*)

Kanto Special Steel Works Ltd., Fujisawa, Japan. (*Forgings*)

Kawaguchi Metal Industries Co. Ltd., Kawaguchi, Japan. (*Castings*)

Kawasaki Heavy Ind. Ltd., Crushing Plant Mfg. Division, Tokyo, Japan. (*Castings*)

Kawasaki Steel Corporation, Chiba Works, Chiba, Japan. (*Slabs and plates*)

Mitsubishi Heavy Industries Ltd., Yokohama Shipyard and Engine Works, Yokohama, Japan. (*Castings*)

Mitsubishi Metal Corporation, Okegawa Plant, Okegawa, Japan. (*Small castings*)

Mitsubishi Steel Manufacturing Co. Ltd.,

Hirota Works, Fukushima Pref., Japan. (*Ingots and castings*)

Tokyo Works, Tokyo, Japan. (*Billets, bars and small forgings*)

Utsunomiya Works, Utsunomiya, Japan. (*Ingots*)

Nakayama Steel Products Co. Ltd., Tsurumi Works, Yokohama, Japan. (*Ingots and plates*)

Nippon Kokan Kabushiki Kaisha.

Keihin Iron Works, Kawasaki, Japan. (*Ingots, plates, tubes, bars and sections*)

Tsurumi Shipyard, Yokohama, Japan. (*Small forgings*)

Nippon Stainless Steel Co. Ltd., Naoetsu Works, Joetsu, Japan. (*Ingots, forgings, castings and plates*)

Nippon Steel Corporation, Japan.

Kamaishi Works, Kamaishi. (*Sections and bars*)

Kimitsu Works, Kimitsu. (*Ingots, sections, plates and electric resistance welded tubes*)

Muroran Works, Muroran. (*Billets, sections and bars*)

Tokyo Works, Tokyo. (*Rolling mills for seamless, rolled or drawn tubes*)

Nippon Yakin Kogyo Co. Ltd., Kawasaki Works, Kawasaki, Japan. (*Ingots, forgings, bars and thin plates*)

Nittoku Metal Industry Co., Ltd., Tokyo, Japan. (*Small forgings*)

Oji Steel Co. Ltd., Gunma Plant, Gunma Pref., Japan. (*Ingots, billets and flat bars*)

Pacific Metals Co. Ltd., Naoetsu Factory, Naoetsu, Japan. (*Ingots and castings*)

Riken Tanzo Co., Ltd., Maebashi Plant, Maebashi, Japan. (*Small forgings*)

Shimizu Kotetsu Co., Ltd., Tokyo, Japan. (*Forgings*)

Shin Nippon Drop Forging Co. Ltd., Kawasaki, Japan. (*Small forgings*)

Sumikin Stainless Steel Tube Co. Ltd., Koga Works, Koga, Japan. (*Fusion welded tubes*)

Sumitomo Metal Industries, Kashima Steel Works, Kashima, Japan. (*Plates*)

Sunnan Iron Works Co., Ltd., Yaizu, Japan. (*Forgings*)



# APPROVED MANUFACTURERS AND PROVING ESTABLISHMENTS

## Yokohama—continued

Tagajo Steel Castings Co. Ltd., Tagajo, Japan. (*Castings*)  
 Taiyo Steel Industries Ltd., Isohara Steel Works, Kita  
 Ibaragi, Japan. (*Small castings*)

Takasaki Metal Industry Co., Ltd., Takasaki Plant,  
 Takasaki, Japan. (*Small castings*)

Tohoku Special Steel Works Ltd., Sendai, Japan. (*Ingots,  
 small forgings, billets and bars*)

Tokushu Seiko (Special Steel Mfg.) Co. Ltd., Kawasaki  
 Plant, Kawasaki, Japan. (*Ingots, forgings and bars*)

Tokyo Chain & Anchor Co., Ltd., Naka-Nippon Factory,  
 Aichi Prefecture, Japan. (*Castings*)

## Yokohama—continued

Tokyo Drop Forging Co. Ltd., Kawasaki Factory, Kawa-  
 saki, Japan. (*Small forgings*)

Tokyo Precision Forging Works Co., Ltd. (Tokyo Seitan  
 Works Co. Ltd.), Ichikawa, Japan. (*Small forgings*)

Toshin Steel Co., Ltd., Tokyo Steel Works, Tokyo, Japan.  
 (*Sections and ingots for forging and plates*)

Tsurumi Steel Tube Co., Ltd., Yokohama, Japan.  
 (*Seamless and welded tubes*)

Uematsu Kozai Kogyo Co., Ltd., Shibayama Works,  
 Chiba Prefecture, Japan. (*Forgings*)

Watanabe Steel Works Co., Ltd., Tokyo, Japan.  
 (*Castings*)

MANUFACTURERS OF ALUMINIUM ALLOYS

The following establishments have complied with the conditions contained in P 12 to P 14 of the Rules and are recognized by the Committee for the manufacture of aluminium alloys for shipbuilding purposes.

**United Kingdom**

Alcan Booth Extrusions Ltd., Banbury. (*Aluminium and alloy extrusions*)  
 Alcan Booth Sheet Ltd., Newport, Mon. (*Aluminium alloys and products*)  
 Alcan Booth Sheet Ltd., Birmingham. (*Aluminium alloys and products*)  
 ALCOA Manufacturing (G.B.) Limited. (*Aluminium alloys and products*)  
 Aluminium Wire & Cable Co., Ltd., Port Tennant, Swansea. (*Aluminium alloys and products*)  
 Birmetals Ltd., Quinton, Birmingham. (*Aluminium alloys and products*)  
 British Aluminium Co., Ltd., Falkirk. (*Aluminium alloys and products*)  
 British Aluminium Co., Ltd., Redditch Works, Birmingham. (*Aluminium alloys and products*)  
 British Aluminium Co., Ltd., Rheola Works, South Wales. (*Aluminium alloys and products*)  
 British Aluminium Co., Ltd., Bank Quay, Warrington. (*Aluminium alloys and products*)  
 High Duty Alloys Ltd., Winscales, Workington. (*Aluminium alloys and products*)  
 E. & E. Kaye, Ltd., Enfield, Middlesex. (*Aluminium alloys and products*)

**Australia**

Alcan Australia Limited.  
 Granville, N.S.W. Works. (*Aluminium alloys and products*)  
 Kurri Kurri, N.S.W. Works. (*Aluminium alloys*)  
 Alcoa of Australia Ltd., Point Henry, Geelong, Victoria, Australia. (*Aluminium alloys and extrusions*)  
 Comalco Products Pty. Ltd.  
 Bell Bay, Tasmania Works. (*Aluminium alloys and products*)  
 Yennora, N.S.W. Works. (*Aluminium alloys and products*)

**Austria**

Vereinigte Metallwerke Ranshofen-Berndorf A.G., Braunau am Inn. (*Aluminium alloys and products*)

**Belgium**

Ateliers Remi Claeys Lichtervelde. (*Aluminium alloy products*)  
 S.A. Sidal, Société de l'Aluminium, Duffel. (*Aluminium alloys and products*)  
 Sidal S.A., Burcht. (*Aluminium alloy products*)

**Canada**

Alcan Canada Products, Ltd., Kingston, Ont. (*Aluminium alloys and products*)  
 Aluminum Company of Canada, Ltd. (No. 1 Plant), Shawinigan Falls, Quebec. (*Aluminium alloy products*)  
 Reynolds Extrusion Co., Ltd.  
 Plant No. 1, St. Therese, Quebec. (*Aluminium alloys and products*)  
 Plant No. 4, Oshawa, Ontario. (*Aluminium alloys and products*)

**Denmark**

Aluminord A/S, Glostrup, Copenhagen. (*Aluminium alloys and products*)

**Finland**

Oy Nokia A.B., Finska Kabelfabriken, Pikkala. (*Aluminium alloys and products*)

**France**

Co. Generale du Duralumin et du Cuivre Cegedur G.P.  
 Faremoutiers 77 (*Aluminium alloys and products*)  
 Groupe Pechiney, Usine de Rive de Gier 42. (*Aluminium alloy products*)  
 Issoire 63. (*Aluminium alloys and products*)  
 Montreuil Belfroy. (*Aluminium alloy products*)

**Germany, Federal Republic of**

Aluminiumwalzwerke Singen G.m.b.H., Singen (Hohentwiel). (*Aluminium alloys and products*)  
 Otto Fuchs, Meinerzhagen. (*Aluminium alloys and products*)  
 Kabel-und Metallwerke Gutehoffnungshütte Aktiengesellschaft, Osnabrück. (*Aluminium alloys and products*)  
 Kaiser Aluminium Europe Inc., Werk Koblenz. (*Aluminium alloys and products*)  
 Reynolds Aluminiumwerke G.m.b.H., Nachrodt. (*Aluminium alloys and products*)  
 VAW Leichtmetallwerke G.m.b.H., Hannover. (*Aluminium alloys and products*)  
 Vereinigte Deutsche Metallwerke A.G., Frankfurt-Heddernheim. (*Aluminium alloys and products*)  
 Vereinigte Aluminium Werke G.m.b.H., Bonn. (*Aluminium alloys and products*)



## APPROVED MANUFACTURERS AND PROVING ESTABLISHMENTS

### Holland

N.V. Nederlandsche Aluminium Maats., Utrecht.  
(*Aluminium alloys and products*)

### India

Indian Aluminium Co., Ltd., Alwaye, Kerala State.  
(*Aluminium alloys and products*)

Indian Aluminium Co., Ltd., Howrah, West Bengal.  
(*Aluminium alloys and products*)

### Italy

Alumetal, S.p.A., Società-Alluminio e Metalli Feltre  
(Belluno) Works. (*Aluminium alloys and products*)

Lavorazione Leghe Leggere, Marghera (Venice).  
(*Aluminium alloys and products*)

Trafilerie e Laminatoi di Metalli S.p.A., Milan. (*Aluminium alloys and products*)

### Japan

Furukawa Aluminum Co., Ltd., Tokyo. (*Aluminium alloys and products*)

Kobe Steel Ltd., Chofu Plant, Shimonoseki. (*Aluminium alloys and products*)

Sky Aluminium Co. Ltd., Fukaya Works, Uwanodai,  
Fukaya City, Saitama Pref. (*Aluminium alloys and products*)

Sumitomo Light Metal Industries Ltd., Nagoya Works,  
Nagoya. (*Aluminium alloys and products*)

### Norway

Alprofil, Raufoss. (*Aluminium alloy products*)

A/S Nordisk Aluminiumindustri, Oslo.

Hoyanger Works. (*Aluminium alloys*)

Holmestrand Works. (*Aluminium alloy products*)

Norsk Hydro A.S., Karmøy Fabrikker, Havik, Karmøy.  
(*Aluminium alloys and products*)

### Poland

Walcownie Metali "Dziedzice".

Czechowice-Dziedzice. (*Aluminium alloy sections, bars and tubes*)

Zakłady Metali Lekkich "Kety", Kety. (*Aluminium alloy, sections and tubes*)

### Spain

Aluminio de Galicia S.A.

Amorebieta Works. (*Aluminium alloys and products*)

La Coruña Works. (*Aluminium alloys and products*)

Sabinanigo Works. (*Aluminium alloys and products*)

Eduardo K. L. Earle, Lejona. (*Aluminium alloys and products*)

Empresa Nacional del Aluminio S.A., Alicante. (*Aluminium alloys and products*)

### Sweden

Gränges Essem, Finspongverken, Finspong. (*Aluminium alloys and products*)

### Switzerland

Aluminium Press & Walzwerk A.G., Munchenstein.  
(*Aluminium alloys and products*)

Aluminium S.A., Menziken. (*Aluminium alloys and products*)

Swiss Aluminium Ltd., Chippis. (*Aluminium alloys and products*)

### U.S.A.

Martin Marietta Aluminium, Inc., Lewisport, Kentucky,  
U.S.A. (*Aluminium alloys and products*)

### Yugoslavia

Impol, Industrija Metalnih Polizdeikov, Slovenska  
Bistrica. (*Aluminium alloys and products*)

Tvornica Lakih Metala "Boris Kidric", Sibenik.  
(*Aluminium alloys and products*)

**MANUFACTURERS OF STEEL WIRE ROPE**

The following establishments have complied with the conditions contained in P 9 of the Rules and are recognized by the Committee for the manufacture of steel wire ropes.

**United Kingdom**

British Ropes Ltd., Doncaster.  
British Ropes Ltd., Gateshead-on-Tyne.  
British Ropes Ltd., London.  
British Ropes Ltd., Retford.  
British Ropes Ltd., (Webster Ropes), Sunderland.  
British Ropes Ltd., Willington Quay, Wallsend-on-Tyne.  
Bruntons (Musselburgh) Ltd., Musselburgh.  
Dawson & Usher Ltd., Sunderland.  
Excelsior Ropes Ltd., Western Ave., Cardiff.  
Firth Cleveland Ropes Ltd., Sheffield.  
Frew Bros. Ltd., Coatbridge.  
Glover Bros. (Mossley) Ltd., near Manchester.  
Hall's Barton Ropery Co., Ltd., Hull.  
John I. Hopper Ltd., Thornaby-on-Tees.  
Latch & Batchelor Ltd., Birmingham.  
Martin, Black & Co. (Wire Ropes), Ltd., Coatbridge.  
Overton Bros. Wire Ropes Ltd., Hull.  
Scottish Wire Rope Co., Ltd. (John I. Hopper Ropes), near Glasgow.  
Shaw, John, Ltd., Worksop.

**Argentina**

Establecimientos Metalurgicos Santa Rosa S.A., Buenos Aires.  
Felix Simon S.A.C.I.F., Buenos Aires.

**Australia**

Australian Wire Rope Works Pty. Ltd., Newcastle, N.S.W.

**Austria**

Felten & Guillaume Fabrik Elektrischer Kabel, Vienna and Bruck an der Mur.  
Joh. Pengg, Draht-und Eisenwerk, 8621 Thörl, Steiermark.  
St. Egydyer Eisen-und Stahl-Industrie-Gesellschaft, St. Aegydam Neuwalde.  
Teufelberger, K., Drahtseilwerke, Wels, Upper Austria.

**Belgium**

Anglo-Continental Ropes, Gilly.  
"Cabcord" (Société Générale de Cablerie et Corderie), Renory.  
Cableries Namuroises S.A., Jambes.  
Cableries & Corderies du Hainaut, S.A., Dour, near Mons.  
Gonzalez Cock S.A., Lokeren.  
Le Lis, S.A., Hamme-sur-Durme.  
Van Praet-Dansaert, Baasrode.

**Brazil**

Cia. Industrial e Mercantil de Artefatos de Ferros, São Paulo.  
Siderurgica Barra Mansa S/A, São Paulo.

**Canada**

Greening Donald Ltd., Hamilton, Ontario.  
Greening Donald Ltd., Midland, Ontario.  
Martin-Black Wire Ropes of Canada Ltd., Pointe Claire, Quebec.  
Wire Rope Industries Ltd., Pointe Claire, Quebec.  
Wire Rope Industries Ltd., Vancouver, B.C.  
Wrights Canadian Ropes Ltd., Vancouver, B.C.

**Chile**

Productos de Acero, Santiago.

**Denmark**

Randersholm A/S., Randers.

**Finland**

Oy Teräsköysi, Hämevaara, Nr. Helsinki.

**France**

Cablerie Saint-Moritz, Reichshoffen (67).  
Société Anonyme des Hauts Fourneaux de la Chiers, Département des Tréfileries & Câbleries, Le Havre.  
Société Anonyme des Hauts Fourneaux de la Chiers, Département des Tréfileries & Câbleries, Faubourg de Lyon, Bourg en Bresse.  
Laminoirs-Tréfileries-Cableries de Lens, Lens.  
Tréfileries de Chatillon-Gorcy S.A. Usine de Sainte-Colombe-sur-Seine-21.



## APPROVED MANUFACTURERS AND PROVING ESTABLISHMENTS

### Germany, Federal Republic of

Arbed S.A., Arbed-Felten & Guillaume, Vereinigte Drahtwerke, Köln-Mülheim.  
 Bertram, J., K.G. Drahtseilwerk, Soest.  
 Bremer Drahtseilerei Luling & Co., Bremen-Hemelingen.  
 Dietz, August Rich. & Sohn, Draht- & Hanseilwerk, Neustadt, nr. Coburg.  
 Drahtseilerei Gustav Kocks G.m.b.H., Mülheim (Ruhr)—Broich.  
 Drahtseilwerke G.m.b.H., Bremerhaven.  
 Gempt, J. H., Lengerich/Westf.  
 Georg Heckel G.m.b.H., Draht-und Drahtseilfabrik, Saarbrücken.  
 Norddeutsches Drahtseilwerk, A. Brinkmann, Syke.  
 Seilindustrie Ernst Deifuss, Unna/Westf.  
 Seilwerke Heinrich Puth K.G., D432 Hattingen, Ruhr.  
 Seilwolff, Aktiengesellschaft für Seilindustrie, Vormal's Ferdinand Wolff, Mannheim, Germany.  
 Vereinigte Drahtseilwerke G.m.b.H., Dortmund.  
 Vornbäumen, J. & W., K.G., Bad Iburg.  
 Westfälische Union A.G., Drahtseilerei, Werk Gelsenkirchen.  
 Westfälische Union, Werk Neheim.  
 Wolf, Gustav, Gütersloh.

### Greece

D. Koronakis S.A., Eleon Works, Thivai.  
 N. Leventeris A.G., Viomichaniki Periochi, Volos.

### Holland

Den Haan Staalkabelfabriek N.V., Gorinchem.  
 Vereenigde Touwfabrieken, Leiderdorp.

### India

Bombay Wire Ropes Ltd., Bombay.  
 Eldee Wire Ropes Ltd., Bombay.  
 Fort William Company Limited, Steel Wire & Rope Division, Calcutta.  
 J. K. Steel Ltd., Calcutta.  
 Mohatta & Heckel Ltd., Khopoli.  
 South India Wire Ropes Ltd., Kerala State.  
 United Wire Ropes Ltd., Bombay.  
 Usha Wire Ropes (Export Division), Ranchi.

### Israel

Wire Rope Works Messilot Ltd., Doar Na Gilboa.

### Italy

Acciaierie Ferriere Lombarde Falck, Sesto San Giovanni.  
 BISWRO, British & Italian Standard Wire Ropes, S.p.A., Bosconero, Turin.  
 Ferriere Giuseppe C.I.M.A. S.p.A., Lecco.

### Italy—continued

Giuseppe & Fratello Redaelli S.p.A.,—Gardone val Trompia (Brescia), Brescia.  
 Industrie Metallurgiche Piemontesi, Susa.  
 Societa Italiana Derivati Vergella, S.p.A. (D.E.R.I.V.E.R.), Sezione di Torre Annunziata.  
 Stabilimenti G. Fornara & Co., Turin.

### Japan

Ako Rope & Wire Mfg. Co. Ltd., Ako.  
 Igeta Wire Rope Co. Ltd., Izumisano.  
 Kasuga Seiko Co. Ltd., Osaka.  
 Kawatetsu Wire Products Co. Ltd., Chiba.  
 Kokoku Steel Wire Ltd.,  
     Niigata Works, Niigata.  
     Osaka Works, Kaizuka.  
 Nankai Sensyu Steel Wire & Rope Co., Ltd., Kaizuka.  
 Nippon Steel Wire Rope Co., Ltd., Osaka.  
     Izumifuchu Factory, Izumi.  
     Izumisano Factory, Izumisano.  
 Nishida Wire Rope Mfg Co. Ltd., Izumisano.  
 Shinko Wire Co., Ltd.,  
     Amagasaki Works, Amagasaki.  
     Onoe Works, Kakogawa.  
     Osaka Works, Izumisano.  
 Tatsumi Rope Mfg. Co. Ltd., Kaizuka.  
 Teikoku Sangyo Co. Ltd., Tsuda Works, Kaizuka.  
 Tokyo Rope Mfg. Co., Ltd.,  
     Izumisano Works, Izumisano.  
     Kokura Works, Kitakyushu.  
     Tsuchiura Works, Tsuchiura.

### Korea

Dong-il Steel Manufacturing Co. Ltd., Yeongdeungpoku Plant.  
 Korea Iron & Steel Wire Co., Ltd., Busan.

### West Malaysia

Berjaya Kawat Berhad; Shah Alan Industrial Estate, Selangor, West Malaysia.

### Mexico

CAMESA S.A., Mexico.

### Norway

Elkem-Spigerverket A/S, Stål og Tau, Mandal.  
 Elkem-Spigerverket A/S, Stål og Tau, Tonsberg.  
 Norsk Staaltaugfabrik, Trondheim.

### Pakistan

Chaudhri Wire Rope Industries Ltd., Lahore.

**Poland**

Slaskie Zakłady Lin i Drutu "Linodrut", Zabrze, ul. Sobieskiego 1.

*Works:* Bytom-Karb, Zakład Z3.  
Sosnowiec, Zakład Z2.

**Portugal**

Companhia Industrial de Cordoarias Texteis e Metalicas, Quintas and Quintas Sarl, Pova do Varzim.

Cordoaria Lisbonense, Lisbon.

Rodrigues d'Oliveira, M., Sa & Fos, Ltda., Oporto.

**South Africa**

Haggie Rand Ltd., Johannesburg.

*Subsidiary Companies.*

Haggie, Son & Love (1936) Ltd., Jupiter Rope Works, Cleveland.

Rand Ropes, Ltd., Germiston.

**Spain**

Forjas y Alambres de Cadagua, Bilbao.  
Franco Espanola de Alambres, S.A., Bilbao.  
"Nueva Montana Quijano", S.A., Santander.  
Trenzas y Cables de Acero S.A., Barcelona.

**Sweden**

Garphytte Bruks A/B., Garphyttan.  
Gunnebo Bruks A/B Varberg.  
Lesjofors A/B., Lesjofors.  
Stallinefabriken, David Ahlquist A/B., Roslags-Nasby.  
Uddeholms A/B., Blombacka Bruk, Lindfors.

**United Arab Republic**

Copper Works, Hagar el Nawatia, Alexandria.

**United States of America**

The Wire Rope Corporation of America, St. Joseph, Missouri.

**Yugoslavia**

Novosadska Fabrika Kabela, Novi Sad.  
"Otocanka", Zadar.



# APPROVED MANUFACTURERS AND PROVING ESTABLISHMENTS

## MANUFACTURERS OF ELECTRICALLY WELDED STEEL CHAIN CABLES and CAST STEEL CHAIN CABLES

The following establishments have complied with the requirements for manufacture of electrically welded and cast steel chain cables and have been recognized by the Committee:—

- GRADE U 1 (a) *Flash butt welded chain cables of mild steel having a tensile breaking strength of 300 to 400 N/mm<sup>2</sup>.*  
 GRADE U 1 (b) *Flash butt welded chain cables of mild steel having a tensile breaking strength of 400 to 490 N/mm<sup>2</sup>.*  
 GRADE U 2 (a) *Flash butt welded or drop forged special quality steel having a tensile breaking strength of 490 to 640 N/mm<sup>2</sup>.*  
 GRADE U 2 (b) *Cast steel having a minimum tensile breaking strength of 490 N/mm<sup>2</sup>.*  
 GRADE U 3 (a) *Flash butt welded or drop forged extra special quality steel having a minimum tensile breaking strength of 690 N/mm<sup>2</sup>.*  
 GRADE U 3 (b) *Cast steel having a minimum tensile breaking strength of 690 N/mm<sup>2</sup>.*

NOTE: Before acceptance on classed ships, chain cables must be tested on a chain testing machine recognized by the Society.

FIRM	GRADE & TRADE NAME (IF ANY)	MAXIMUM DIAMETER	SURVEYING DISTRICT
<b>United Kingdom</b>			
Barzillai Hingley & Sons Limited, Cradley Heath, Staffs.	U 1 (b) (Stud link & Short link)	$\frac{5}{8}$ in	Birmingham
Beal & Son (Cable Makers) Ltd., Cardiff.	U 1 (a), U 1 (b) & U 2 (a) U 2 (a) (Meyer, Roth and Pastor)	4 in $1\frac{3}{8}$ in	Cardiff
Bradney Chain & Engineering Co. Ltd., Quarry Road, Dudley, Worcs.	U 1 (b) (Short link)	$\frac{1}{2}$ in	Birmingham
Brown, Lenox & Co. Ltd., Pontypridd.	U 2 (b)	3 in	Cardiff
Griffin-Woodhouse Ltd., Cradley Heath, Staffs.	U 2 (a) (Integral stud)	76 mm	Birmingham
Lloyds (Brierley Hill) Ltd., Brierley Hill, Staffs.	U 1 (a), U 1 (b) & U 3 (a) U 2 (a) (Tayco) U 2 (a) (New Process Tayco)	2 in 2 in 2 in	Birmingham
Norbrit-Pickering Ltd., Wishaw, Lanarkshire.	U 1 (a), U 1 (b), U 2 (a) & U 3 (a)	$4\frac{1}{2}$ in	Glasgow
Parsons Chain Co. Ltd., Stourport-on-Severn.	U 1 (a), U 1 (b) & U 2 (a) (Short link)	$1\frac{1}{4}$ in	Birmingham
Wheway Watson (C.M.) Ltd., Walsall.	U 1 (a) U 1 (b) (Short link)	$\frac{7}{8}$ in $\frac{11}{16}$ in	Birmingham

# LLOYD'S REGISTER OF SHIPPING

FIRM	GRADE & TRADE NAME (IF ANY)	MAXIMUM DIAMETER	SURVEYING DISTRICT
<b>Australia</b>			
Falkiner Chains Pty. Ltd., Brisbane.	U 1 (a)	3 $\frac{3}{16}$ in	Brisbane
	U 1 (b)	$\frac{3}{4}$ in	
	(Short link)		
	U 2 (a)	3 $\frac{3}{16}$ in	
<b>Austria</b>			
Ferdinand Freiherr v. Helldorff & Otto Rothart Ketten- werk Brückl, Brückl.	U 1 (a)	26 mm	Vienna
	(Short link)		
Steirische Kettenfabriken Pengg-Walenta Kommanditgesellschaft, Styria.	U 1 (a)	44 mm	Vienna
	U 1 (b) & U 2 (a)	41 mm	
<b>Belgium</b>			
Adh-Demanet, Gosselies.	U 1 (a), U 1 (b) & U 2 (a)	76 mm	Antwerp
	U 3 (a)	63 mm	
<b>Brazil</b>			
Companhia de Parafusos Metalurgia Santa Rosa, São Paulo.	U 1 & U 2 U 3	2 in. 1 $\frac{7}{8}$ in.	São Paulo
<b>Finland</b>			
Fiskars A.B., Loimaa.	U 1 (a)	36 mm	Abo
Oy Wartsilä A.B., Dalsbruk Works, Dalsbruk.	U 1 (a), U 1 (b) & U 2 (a)	64 mm	Abo
<b>France</b>			
M. Carlier & Cie., St.-Amand-les-Eaux (Nord).	U 1 (a) & U 1 (b)	30 mm	Valenciennes
Davaine Fils et Cie., St.-Amand-les-Eaux (Nord).	U 1 (a) & U 1 (b)	30 mm	Valenciennes
Etablissements Marit, Saint-Amand-les-Eaux (Nord).	U 1 (a) & U 1 (b)	44 mm	Valenciennes
	U 2 (a)	46 mm	
Sirot-Metallurgie S.A., Saint-Amand-les-Eaux (Nord).	U 1 (a), U 1 (b) & U 2 (a)	100 mm	Valenciennes
	U 3 (a)	150 mm	
	U 1 (a), U 1 (b) & U 2 (a) (Etaifix)	123.5 mm	Valenciennes
	U 3 (a) (Etaifix)	125 mm	
A. Veille et Cie., Le Havre.	U 1 (a), U 1 (b) & U 2 (a)	100 mm	Havre
	U 1 (a), U 1 (b) & U 2 (a)	91 mm	
	(Monobloc)		
	U 3 (a)	87 mm	
<b>Germany, Federal Republic of</b>			
Dortmunder Kettenfabrik B. Mester, Dortmund.	U 1 (a) & U 2 (a)	69 mm	Dortmund
	U 3 (a)	81 mm	



APPROVED MANUFACTURERS AND PROVING ESTABLISHMENTS

FIRM	GRADE & TRADE NAME (IF ANY)	MAXIMUM DIAMETER	SURVEYING DISTRICT
<b>Germany, Federal Republic of—continued</b>			
Joto-werk, Josef Topp Kettenfabrik, Warmen (Ruhr).	U 1 (a) & U 1 (b) U 2 (a) U 3 (a)	68 mm 62 mm 88 mm	Dortmund
Kettenfabrik Kalthof, August Thiele; August Thiele G.m.b.H. Fabrik für Ketten und Kettenforderer, Kalthof, near Schwerte-Ruhr.	U 1 (a), U 1 (b) & U 2 (a) U 3 (a)	140 mm 132 mm	Dortmund
Kettenwerke Schlieper, Letmathe-Grüne.	U 1 (a), U 1 (b) & U 2 (a) U 3 (a)	140 mm 132 mm	Dortmund
Heinrich Prunte, Frondenberger Kettenfabrik, Fronder- berg-Ruhr.	U 2 (a)	30 mm	Dortmund
Theile, J. D., Schwerte-Ruhr.	U 1 (a), U 1 (b) & U 2 (a) U 3 (a)	92 mm 102 mm	Dortmund
<b>Holland</b>			
Anker-En Kettingfabriek "Schiedam", Schiedam.	U 2 (a)	78 mm	Rotterdam
<b>India</b>			
Indian Chain Manufacturing Co., Calcutta.	U 1 (b) & U 2 (a)	61 mm	Calcutta
<b>Italy</b>			
Weissenfels, Fusine in Valromana.	U 1 (a), U 1 (b) & U 2 (a)	23 mm	Trieste
<b>Japan</b>			
Hamanaka Chain Manufacturing Co. Ltd., Shirahama Plant, Himeji.	U 1 (a), U 1 (b) & U 2 (a) U 3 (a)	150 mm 155 mm	Kobe
Japan Mechanical Chain Manufacturing Co. Ltd., Osaka.	U 2 (a) (Kikai) U 1 (a) & U 1 (b) (Flash welded) U 2 (a) (Flash welded) U 3 (a) (Flash welded)	64 mm  58 mm  84 mm  102 mm 132 mm	Osaka
Kotobuki Chain Co. Ltd., Hiro.	U 2 (a) (Flash welded) U 3 (a) (Flash welded)	102 mm  132 mm	Nagasaki
Koyo Chain Mfg. Co. Ltd., Osaka.	U 1 (a) & U 1 (b) U 2 (a)	42 mm 66 mm	Osaka
Nippon Seisa Co. Ltd., Himeji.	U 2 (a) (Stud link)	44 mm	Kobe

LLOYD'S REGISTER OF SHIPPING

FIRM	GRADE & TRADE NAME (IF ANY)	MAXIMUM DIAMETER	SURVEYING DISTRICT
<b>Japan—continued</b>			
Osaka Chain & Machinery Co. Ltd., Kaizuka.	U 2 (a) & U 2 (b)	146 mm	Osaka
	U 3 (a) & U 3 (b) (Stud link)	147 mm	
Taiyo Chain Mfg. Co. Ltd., Himeji.	U 2 (a) (Flash butt welded)	60 mm	Kobe
Tokiwa Kogyo Co. Ltd., Himeji.	U 2 (a)	107 mm	Kobe
Tokyo Chain & Anchor Co. Ltd., Aichi Prefecture.	U 1 (a), U 1 (b), U 2 (a) & U 2 (b)	150 mm	Yokohama
	U 3 (a)	120 mm	
<b>Korea</b>			
Dai Han Anchor Chain Mfg. Co. Ltd.	U 2 (a)	77 mm	Busan
<b>Norway</b>			
Norsk Kjettingindustri A/S, Mandal.	U 1 (a) (Short link)	25 mm	Oslo
	U 1 (a) (Stud link)	32 mm	
	U 2 (a) (Stud link)	27 mm	
<b>Poland</b>			
Slupskie Zaklady Sprzetu Okretowego, Slupsk.	U 2 (a)	76 mm	Gdansk
<b>Rumania</b>			
Interprinderea Sirmei Cuiele si Lanturi "TREFO"	U 1	54 mm	Galatz
	U 2 (a)	53 mm	
<b>South Africa</b>			
McKinnon Chain (South Africa) (Pty) Ltd., Vereeniging.	U 1 (a) (Short link)	$\frac{3}{4}$ in	Vereeniging
	U 1 (a), U 1 (b) & U 2 (a)	2 in	
<b>Spain</b>			
Cadenas y Forjados, S.A., Lejona-Vizcaya.	U 1 (a), U 1 (b) & U 2 (a)	95 mm	Bilbao
	U 3 (a)	76 mm	
Don Ciriaco Rodriguez Dorado, Barcelona.	U 1 (a) & U 1 (b)	30 mm	Barcelona
	U 2 (a)	26 mm	



APPROVED MANUFACTURERS AND PROVING ESTABLISHMENTS

FIRM	GRADE & TRADE NAME (IF ANY)	MAXIMUM DIAMETER	SURVEYING DISTRICT
<b>Spain—continued</b>			
Vicinay S.A., Deusto.	U 1 (a) & U 1 (b)	95 mm	Bilbao
	U 2 (a)	122,5 mm	
	U 3 (a)	114 mm	
<b>Sweden</b>			
Bergvik & Ala AB, Ljusne-Industrierna, Ljusne.	U 1 (b)	92 mm	Stockholm
	U 1 (a), U 2 (a) & U 3 (a)	155 mm	
Bulten Kanthal AB, Ramnäs Bruks Divisionen, Ramnäs.	U 1 (a), U 1 (b) & U 2 (a)	98 mm	Stockholm
	U 3 (a)	152 mm	
Gunnebo Bruks Aktiebolag, Gunnebobruk.	U 1 (a) & U 1 (b)	16 mm	Stockholm
Orsa Kättingfabrik A/B, Orsa.	U 1 (a), U 1 (b) & U 2 (a)	55 mm	Stockholm
<b>United Arab Republic</b>			
El Nasr Forgings, Cairo.	U 1 (a)	38 mm	Alexandria
<b>United States of America</b>			
Baldt Anchor and Chain Division of Baldt Corp., Chester, Pennsylvania.	U 2 (a) (Weld in alternate links)	$\frac{5}{8}$ in	Philadelphia
	U 2 (a) (Flash butt welded)	$4\frac{1}{4}$ in	
	U 3 (a) (Flash butt welded)	$3\frac{3}{8}$ in	
	U 3 (a) (Di-Lok drop forged)	$3\frac{3}{8}$ in	
<b>Yugoslavia</b>			
Tovarna Verig, Lesce.	U 1 (a), U 1 (b) & U 2 (a)	100 mm	Rijeka
	U 3	100 mm	

PROVING ESTABLISHMENTS

The following establishments have been recognized by the Committee for the testing of anchors and chain cables in accordance with the Society's Rules. Anchors and chain cables intended for ships of United Kingdom Registry must be tested at establishments certified under the terms of the United Kingdom Anchors and Chain Cables Act 1967.

**Argentina**

Direccion General de Administracion Naval, Buenos Aires.

**Australia**

Falkiner Chains Pty. Ltd., Brisbane, Queensland (for testing chain cables up to 250 tons).

**Austria**

Ferdinand Freiherr v. Helldorff & Otto Rothart Kettenwerk Brückl, Brückl, Carinthia.

Steirische Kettenfabriken Pengg-Walenta Kommanditgesellschaft, Werk Hansenhütte, Kapfenberg-Hansenhütte, Styria.

**Belgium**

Adh. Demanet, Gosselies (for testing chains up to 300 tons).

Béliard, Murdoch & Co., Antwerp (for testing anchors and chain cables up to 100 tons).

Mercantile Marine Engineering & Graving Dock Co., Antwerp.

**Brazil**

Acos Villares, São Paulo (for testing anchors only).

Industrias Zauli Rio Branco S.A., São Paulo.

**Canada**

Canada Chain & Forge Co., Ltd., Granville Island, Vancouver, B.C.

Dominion Chain Co., Ltd., Stratford, Ontario.

Drummond, McCall & Co., Ltd., Quebec.

Lister Bolt & Chain Works, Ltd., Richmond, B.C.

**Finland**

Fiskars A.B., Loimaa.

Oy Wärtsilä A/B., Dalsbruk, Helsingfors (for testing anchors up to 150 tons and chain cables up to 250 tons).

**France**

Carlier et Cie., St. Amand-les-Eaux (Nord).

Davaine, Fils et Cie., St. Amand-les-Eaux (Nord) (for testing chain cables up to 132 tons).

Ets. Marit, St. Amand-les-Eaux (Nord).

Manufacture de Chaines et Ancres de Saint-Amand, Etablissements Sirot-Mestreit and Dorémieux Reunis, Saint-Amand-les-Eaux (Nord).

Paoli, J., & Co., Marseilles.

Société des Forges d'Arcenc, Marseilles.

Veille, A., & Co., Le Havre.

**Germany, Federal Republic of**

Blohm & Voss A.G., Hamburg.

Dortmunder Kettenfabrik Bernhard Mester, Wetterstr. 10, Dortmund.

Duisberger Kettenfabrik und Hammerwerk, H. d'Hone, Duisburg.

Eisenwerk und Apparatebau Gebr. Knauer, Abteilung Hammerwerk Heuss (Mannheim).

Fröndenberger Kettenfabrik, Heinrich Prünte, Frondenberg-Ruhr (for testing chain cables up to 120 tons).

Wilhelm Gröhnke, Hamburg.

Hoesch Hüttenwerke A.G., Werk Phoenix Hörde, Dortmund-Hörde (for testing anchors only).

Howaldtswerke A.G., Hamburg.

Joto-Werk Josef Topp, Kettenfabrik, Warmen (Ruhr).

Kettenfabrik Kalthof, August Thiele; and August Thiele G.m.b.H., Fabrik für Ketten und Kettenforderer, Kalthof, near Schwerte-Ruhr.

Kettenwerke Schlieper, Letmathe-Grüne.

Theile, J. D., Schwerte-Ruhr.

**German Democratic Republic**

V.E.B. Schwermaschinenbau Kombinat, "Ernst Thalmann", Magdeburg-Buckau.

**Gibraltar**

H.M. Dockyard, Gibraltar.

**Greece**

Athens National Technical University.

**Holland**

Koninklijke Nederlandsche Grofsmederij, Leiden.

N.V. Anker- & Kettingfabriek "Schiedam" (*Managing Director*: P. Th. Verhoeff), Schiedam.

G. Schut Hzn. Scheepssmederij, Amsterdam.

**Hong Kong**

Hong Kong United Dockyards Ltd.

**Hungary**

Kohó-és Gépipari Miniszterium, Budapest, Works: Kéziszerszámgár, Budapest.

**India**

Bombay Port Trust, Mazagon, Bombay 10.

The Commissioners for the Port of Calcutta, Calcutta.

Garden Reach Workshops Ltd., Calcutta. (for testing anchors only).

Indian Naval Dockyard, Lion's Gate, Bombay.



## APPROVED MANUFACTURERS AND PROVING ESTABLISHMENTS

### Italy

Acciaierie Weissenfels, Catenificio, Fusine di Valromana, Udine (for the testing of small chains only).  
Neptunia S.r.L., Genoa.

### Japan

Hamanaka Chain Manufacturing Co., Ltd., Shirehama Plant, Himeji.  
Japan Mechanical Chain Manufacturing Co., Ltd., Osaka.  
Kotobuki Industries Co., Ltd., Hiro Works, Kure.  
Koyo Chain Manufacturing Co., Ltd., Osaka.  
Nippon Chuza Kabushiki Kaisha, Kawasaki, Japan.  
Nippon Seisa Co. Ltd., Himeji.  
Onomichi Anchor Manufacturing Co., Ltd., Fukuyama (for testing anchors only).  
Osaka Chain & Machinery Co., Ltd., Kaizuka Works, Kaizuka.  
Sanyo Seisa Co., Ltd., Himeji.  
Toa Seisa Co., Ltd., Himeji.  
Tokiwa Kogyo Co., Ltd., Himeji.  
Tokyo Chain & Anchor Co., Ltd. Naka-Nippon Works, Aichi Prefecture.

### Korea

Dai Han Anchor Chain Mfg. Co., Ltd., Seoul.

### Malta

Malta Drydock Corporation.

### New Zealand

The Dunedin Engineering & Steel Co., Ltd., Dunedin.

### Norway

Norsk Kjettingindustri A/S, Mandal.

### Poland

Slupskie Zaklady Sprzetu, Okretowego.  
Zaklady Mechaniczne im. Gen. K. Swierczewskiego, Elblag.

### Singapore

Sembawang Shipyard (Pte) Ltd.

### South Africa

McKinnon Chain (South Africa) (Pty.) Ltd., Vereeniging, Transvaal.

### Spain

Aceros de Galicia S.A., Vigo, Spain (for testing anchors only).  
Cadenas y Forjados, S.A., Works: Lejona-Vizcaya.  
Don Ciriaco Rodriguez Dorado, Barcelona (for testing chain cables up to 30 tons).  
Forjas de San Martin de Pedro Framis, Barcelona (for testing chains up to 16 tons).  
Vicinay, S.A., Deusto.

### Sweden

Bergvik & Ala A/B, Ljusne-Industrierna, Ljusne.  
Bulten Kanthal AB, Ramnäs Bruks Divisionen, Ramnäs.  
Gunnebo Bruks Aktiebolag, Gunnebobuck, Västervik (for testing chains up to 75 tons).  
Orsa Kättingfabrik A/B, Orsa.  
Statens Provningsanstalt (Government Establishment), Stockholm.

### Turkey

Gemi Zincir Sanayii Kollektif Şirketi, Istanbul.

### United Kingdom

Brown, Lenox & Co., Ltd., Pontypridd, Mon.  
Griffin-Woodhouse Ltd., Cradley Heath, Staffs.  
H.M. Dockyard:  
Chatham.  
Devonport.  
Portsmouth.  
Lloyd's (Brierley Hill) Ltd., Brierley Hill, Staffs.  
Lloyd's British Testing Co. Ltd., Low Walker-on-Tyne, Northumberland.  
Lloyd's British Testing Co. Ltd., Netherton, (near Dudley), Worcs.  
Lloyd's Scottish Testing Co. Ltd., Burnbank, Hamilton, Lanark.  
Lloyd's South Wales Testing House Co. Ltd., Cardiff, Glam.  
Norbrit-Pickering Ltd., Coatbridge, Lanark.

### United States

Baldt Anchor Chain & Forge Division of Baldt Corp., Chester, Pa.  
Baldt Anchor Chain & Forge Division of Baldt Corp., Fieldsboro, N.J.  
Johnson-Farmer Chain Co., Lebanon, Pa.  
Washington Chain & Supply Co., Seattle, Washington.

### Yugoslavia

Tovarna Verig, Lesce pri Bledu.

The testing machines at the following establishments have been recognized by the Committee for the break testing of chain cables in accordance with the Society's Rules. Any proof testing necessary will require to be carried out at one of the above establishments.

### United Kingdom

British Steel Corporation, Britannia Works.  
National Engineering Laboratory, East Kilbride.





# Chapter R

## PROVISIONAL RULES AND GUIDANCE NOTES

### Explanatory Notes

**PROVISIONAL RULES** give requirements which have been framed primarily for the initial regulation of ship and machinery applications in process of development ; they are subject to continuous review.

**GUIDANCE NOTES** are intended as recommendations to designers, based on good practice, in matters for which the present state of knowledge does not justify precise requirements.

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### R (B) PROVISIONAL RULES FOR PLASTIC PIPES

#### Section 1

**101** Proposals to use plastic type materials in ship-board piping systems will be considered in relation to the properties of the materials, the operating conditions of temperature and pressure, and the intended service.

The Rules which follow are intended for extruded plastic pipes; they may also be used, where applicable, for fabricated plastic pipes glass reinforced. Any proposed service for plastic pipes not mentioned in these Rules is to be submitted for special consideration.

**102** A specification of the plastic material giving mechanical and thermal properties is to be submitted for consideration.

**103** In general, plastic pipes are not to be used where they will be subjected to temperatures above 49°C or below 0°C.

**104** Plastic pipes of approved type may be used for the following services:—

(a) Air and sounding pipes to tanks used exclusively for carrying water ballast or fresh water, with the exception of the portion above deck.

(b) Sounding pipes to cargo holds.

(c) Water ballast and fresh water pipes situated inside tanks used exclusively for carrying water ballast or fresh water.

(d) Scupper pipes draining inboard provided they are not led within the boundaries of refrigerated chambers.

Items (a) and (b) are not applicable to passenger ships.

**105** Plastic pipes may be used for domestic and similar services for which there are no Rule requirements, as follows:—

Domestic cold salt and fresh water systems.

Sanitary salt water systems.

Sanitary and domestic waste pipes wholly situated above the freeboard deck.

Water pipes associated with air conditioning plants.

**106** Since plastic materials are generally heat sensitive and very susceptible to fire damage, plastic pipes will not be acceptable for services essential to safety, as follows:—

Fire extinguishing pipes.

Bilge pipes in cargo holds.

Bilge and ballast pipes in the machinery space.

Main and auxiliary water circulating pipes.

Feed and condensate pipes.

Pipes carrying oil or other flammable liquids.

**107** If plastic pipes are arranged to pass through watertight or fire-resisting bulkheads or decks provision is to be made for maintaining the integrity of the bulkhead or deck in the event of pipe failure. Details of the arrangements are to be submitted for approval.

**108** Pipes are to be of robust construction, and in general so designed that the wall stress will not exceed  $\frac{1}{7}$  of the tensile strength of the material at the working temperature. Particulars of scantlings and joints are to be submitted for consideration.

**109** All pipes are to be adequately but freely supported; suitable provision for expansion and contraction is to be made in each range of pipes to allow for large movements between plastic pipe and steel structure—the coefficient of thermal expansion for plastics being eight or more times that of steel.

**110** All fittings and branches are to be suitable for the intended service having joints of cemented, flanged, or other approved type.

**111** The strength of the plastic material is to be checked at the Surveyor's discretion. The tensile strength is to be determined by pressure tests to destruction on sample pipes. The pressure is to be so applied that failure of the pipe occurs in not less than five minutes. Bulging of the pipe during test is acceptable. The tensile strength is to be taken as the hoop stress at failure based on the original pipe dimensions.



## R (C) PROVISIONAL RULES FOR THE CLASSIFICATION OF NUCLEAR SHIPS

**Section 1****GENERAL**

101 The class notation "Nuclear Powered" will be assigned, in accordance with the provisions of Chapter B, to sea-going ships equipped with a nuclear reactor or reactors for main propulsion and built in accordance with, or equivalent to, the relevant Rules and the following special requirements.

102 The requirements of Chapters C to Q apply as may be relevant to nuclear-powered ships, except as otherwise required by the following Rules.

**HULL**

103 Containment of the reactor, primary circuit and associated equipment is to be provided by the containment structure, which may be integral with the hull or of a pressure vessel type independent of the hull. *See* 118 to 122.

104 The containment protection length is the overall length of the containment structure plus a marginal length at each end. The marginal length is to be not less than B/5 with a minimum of 3 m.

**Quality of Material**

105 The material of the containment structure, if integral with the hull, and of the deck, sheerstrake, side and bottom shell plating, including keel, over the containment protection length and over the breadth of the ship is to be of Grade E or Grade EH steel (*see also* 118).

**Longitudinal Strength**

106 The minimum section modulus for the hull shall be in accordance with the requirements of D 3, but the stress levels (*see* Table D 3.4) will be specially considered.

107 Continuity of longitudinal strength members is to be provided, and rapid changes of section are to be avoided. The scantlings in way of the containment structure will be specially considered for each case. *See* 121.

108 If shielding is attached to the hull structure, the arrangements will be specially considered for each case.

**External Shock**

109 The support system for the reactor and associated components is to be designed to withstand a shock or impact acceleration of 3 g in any direction without general deformation of the structure.

**Collision and Grounding Protection**

110 No part of the containment structure is to extend outside a vertical datum B/5 metres inboard of the ship's side at the load waterline (*see also* 115).

111 The structure of the ship below the reactor and at the sides in way of the containment protection length will require to be specially considered from the aspect of absorption of the energy of collision and grounding forces.

112 Details of the side shell framing and collision protection structure in way of the containment protection length are to be submitted for approval.

113 A double bottom structure of depth as required by D 904, but not less than 1,85 m is to be fitted in way of the reactor and is to incorporate a system of longitudinal framing in association with bottom transverses.

114 The integration of the containment with the hull structure is to be such that the bottom shell in way of the reactor is to be capable of sustaining comparatively severe local damage without prejudicing the support of the reactor and its relative position in the ship.

115 A watertight longitudinal bulkhead (which may form part of the containment structure) is to be fitted between the reactor and the ship's side, not less than 1,5 m from the inner line of primary shell supporting members at the load waterline. The minimum clearance between this bulkhead and the reactor installation will be considered in association with the form of collision protection adopted. This bulkhead is generally to be in line with similar longitudinal material in the half length amidships, but alternative arrangements for continuity will be specially considered.

116 Proposals for the carriage of liquids, or siting of auxiliary machinery, abreast the reactor installation will be the subject of special approval.



**Hazard from Cargo**

117 The reactor compartment is to be isolated from the cargo spaces by cofferdams. Machinery spaces and pump rooms will be regarded as equivalent to cofferdams. Transverse cofferdams are to extend for the breadth of the ship. The strength of cofferdam bulkheads will be specially considered.

**Containment Structure**

118 Where the maximum major accident pressure (see R (C) 501), does not exceed 0,2 N/mm<sup>2</sup> (2 kgf/cm<sup>2</sup>) gauge the containment may be provided by the hull structure.

119 Where containment is provided by a pressure vessel independent of the hull, R(C) 216 to R(C) 225 apply.

120 The arrangements of such a containment structure are to be such that the transmission of stresses from the hull structure is reduced to a minimum, and are to be specially approved.

121 The design stresses and calculation methods for containment structures which are integral with the hull are to be specially approved. Temperature effects will be specially considered. The structure is also to be capable of withstanding an external pressure of 0,34 N/mm<sup>2</sup> (3,5 kgf/cm<sup>2</sup>) gauge.

122 The containment structure is to be tested by hydraulic pressure to 1,25 times the design pressure and is to be leak tested in accordance with R (C) 225, or alternative acceptable means of test.

**Section 2****PRESSURE VESSELS AND COMPONENTS**

201 Pressure vessels and components for nuclear installations are to be considered in the following categories:—

**Category "A"**

Pressure vessels and components which are:—

1. Intended to contain radioactive materials in service,  
and
2. Either (i) subject to direct neutron irradiation such that the physical properties of the materials of construction will be significantly affected during the projected life of the nuclear installation, or (ii) inaccessible for normal comprehensive periodic examination and maintenance from biological considerations of radioactivity.

**Category "B"**

Pressure vessels and components which are:—

1. Intended to contain radioactive materials in service,  
and
2. May be subject to direct neutron irradiation but not such that the physical properties of the materials of construction will be significantly affected during the projected life of the nuclear installation, but which will be accessible for normal comprehensive examination and maintenance at any selected time during the projected life of the nuclear installation.

**Category "C"**

Pressure vessels and components which are:—

1. Not intended to contain radioactive materials in service.
2. May be subject to direct neutron irradiation but not such that the physical properties of the materials of construction will be significantly affected during the projected life of the nuclear installation and which will be accessible for normal comprehensive examination and maintenance at any selected time during the projected life of the nuclear installation.

**Category "A"**

202 The materials of construction of these vessels are to be of a readily weldable quality, of adequate corrosion resistance and chosen from types which have been proven in pressure vessel service under similar conditions for non-nuclear applications. Data relating to the probable behaviour of materials under irradiation should be available.

203 Irradiation monitoring specimens representative of the materials of construction and of the welding of the vessels are to be provided. A programme of monitor specimen testing is to be drawn up covering the projected life of the nuclear installation.

204 Pressure vessels are to be designed and constructed generally in accordance with a code approved by the appropriate National Authority.

The design conditions to be adopted are as follows:—

Design pressure is to be not less than the maximum permissible working pressure under normal continuous and transient operation. Additionally, the relief valves must ensure that under emergency conditions the accumulation pressure must not exceed 1,10×maximum permis-



sible working pressure. There should be a margin between the normal pressure at which the pressure vessel operates and the lowest pressure at which any safety valve is set to lift, to prevent unnecessary lifting of the safety valve.

Design temperature to be the maximum coolant temperature under normal operating conditions.

**205** The effect of the following factors on stress levels must also be taken into consideration:—

- (a) (i) Internal and external loading applied by or through circuits, supports and other connections, and self weight.
- (ii) Temperature differentials and gradients occurring during normal operation, including start-up and shut-down.
- (b) Shock and impact loading (*see* R (C) 109 and R (C) 522).

**206** Special attention is to be given to effecting a clean design minimizing stress concentrations. Reinforcement of major nozzle and other openings in the main pressure shell by the use of doubling plates is not permitted. Weldments are to be designed to permit 100 per cent radiography wherever possible.

**207** The weld procedure specification is to be prepared giving details of the proposed methods of fabrication, including all pertinent welding variables and proposed methods of non-destructive examination. The specification must also include proposals in respect of the following:—

- (a) Weld procedure tests to prove the proposed methods.
- (b) Welding operator tests to prove each welder's ability.
- (c) Production tests to prove the maintenance during fabrication of the standard of welding established and approved under weld procedure tests. Such tests are to be representative of the final conditions of the welding of the completed vessels and components.

The above tests are to be carried out under the conditions obtaining during fabrication.

**208** On completion of fabrication, a hydraulic test is to be applied to a pressure in accordance with the requirements of the approved code.

#### Category "B"

**209** The requirements for vessels in this category are as for Category "A", except that irradiation data on materials is not required.

Internal and external access for normal comprehensive periodic examination of all vessels and components which are accessible from biological considerations of radioactivity is to be provided.

**210** The pressure tightness of fuel assembly containers and associated coolant systems should also be considered in this category. Where closure of the pressure shell is effected by mechanical means, facilities are to be provided to test the integrity of the joint against leakage at any selected time.

#### Categories "A" and "B"

**211** Vessels and components of the primary circuit are to be shop fabricated and shop tested wherever possible. The number of *in situ* closing welds must be kept to a minimum and adequate access is to be provided in each case.

**212** On completion, the installation of the primary circuit is to be tested in accordance with the approved code. A leak test is also to be applied to the completed primary circuit for each proposed installation in a manner approved by the Society.

**213** Provisions are to be made to facilitate periodic pressure and leak testing of the primary circuit.

**214** Construction of these vessels is to be carried out in such a way that the high standard of cleanliness required can be attained.

#### Category "C"

**215** Vessels in this category are to be designed, constructed and tested in accordance with the Rules for Welded Pressure Vessels (Chapter J) or other approved code or specification.

#### Containment

**216** Materials for the construction of these structures are to be of a readily weldable quality and chosen from types which have been proven in service.

**217** Where part of the ship structure is used as containment, R (C) 118 and R (C) 122 and 123 are applicable.

**218** Pressure vessels are to be designed and constructed generally in accordance with a code approved by the appropriate National Authority.

**219** No means of internal pressure relief are to be fitted. The design conditions to be adopted are as follows:—

Design pressure (internal) is normally to be the major accident pressure in  $\text{N/mm}^2$  ( $\text{kgf/cm}^2$ ) gauge, *see* R (C) 501.



Collapse pressure (external) is to be not less than 0,34 N/mm<sup>2</sup> (3,5 kgf/cm<sup>2</sup>). Arrangements to protect the vessel when subjected to pressure in excess of the collapse pressure should be submitted for approval.

Temperature effects are to be considered, *see* R (C) 502.

220 The following factors are also to be taken into consideration:—

- (a) Internal and external loading applied from ship's motion, machinery installation and shielding.
- (b) Shock and impact loading, *see* R (C) 109 and R (C) 522.

221 Where it is envisaged that items of equipment within the containment will be removed or replaced during the life of the installation, adequate shipping openings with mechanical closures are to be provided to avoid recourse to cutting the containment structure in service.

222 The number and size of all openings in the pressure shell are to be kept to a minimum.

Isolating valves must be provided for all pipe circuits penetrating the pressure shell. The positioning of the isolating valves with details of the arrangements for their operation and control are to be submitted for approval.

223 A weld procedure specification is to be provided.

224 On completion of fabrication an internal pressure test is to be applied in accordance with the approved code.

225 A leak test to enable the determination of leakage rates from the containment structure at design pressure is to be conducted. Leakage from the containment structure should be kept to a practical minimum. The target figure to be adopted is 1 per cent in 24 hours of the free volume of the gaseous content in the containment vessel with all machinery installed.

#### Pressure Control and Over-pressure Relief

226 For each pressure vessel in the primary and secondary circuits in which it is possible under any foreseeable conditions for the pressure to rise above the maximum design pressure, over-pressure relief must be possible.

227 The design requirements for primary and secondary pressure control systems are to include an agreed failure of the primary/secondary boundary. The effect of the consequent transfer of fluid from the primary to the secondary circuit or from the secondary to the primary circuit is to be assessed.

Discharge from primary pressure circuits is to be contained, *see* R (C) 514.

228 In systems where it is practicable to provide total relief capacity during any emergency condition by fitting one safety valve only, an additional safety valve of equivalent capacity is to be fitted. In multi-valve systems, additional safety valves are to be fitted in excess of the number required to provide total relief capacity. The number of additional valves to be provided will depend on the operational reliability of the safety valve types and the number involved.

Relief systems are to be designed to provide total relief capacity during any emergency condition with the maximum pressure accumulation of 10 per cent of the design pressure with the additional safety valves isolated.

229 Provision is to be made to detect leakage from each safety valve in normal operation. Provision is to be made to effect isolation of each safety valve during reactor and circuit operation. The shut-off arrangements are to be interlocked to ensure that the number of valves required to effect total relief are on line.

230 A pressure connection is to be provided to enable testing of safety valve lift *in situ*.

If block valves are proposed in safety valve discharge lines, a low pressure bursting disc must be incorporated in the valve design.

231 Proposed departures from the above requirements will be given special consideration.

### Section 3

#### REACTOR ENGINEERING

##### General Requirements

301 Normal reactor and main machinery control during power operation are to be effected from a central control position external to the reactor compartment. An emergency reactor shut-down position with monitoring instrumentation is to be provided remote from the central control position.

302 Where isolation of the primary flow between reactor and heat exchanger is not provided, means of individual remote isolation of the secondary side of the heat exchangers is to be provided adjacent to the heat exchangers.

303 Individual isolation of the primary coolant subsidiary circuits is to be provided.



304 Data on the expected degree of irradiation effect to moderator and coolant is to be provided and the proposed method of monitoring and controlling such effect throughout ship life is to be stated.

305 Materials of construction which come into contact with primary fluid should be examined in relation to the build up of corrosion products activity within the reactor system. Details of proposed coolant treatment facilities are to be supplied.

306 Data and, if possible, experimental evidence relating to the power stability of the reactor under regular cyclic motions up to accelerations of 0.45 g as may be obtained in a seaway are to be provided. As a design criterion a period of 12 seconds should be used regardless of size and type of ship or position of reactor.

307 Special consideration is to be given to the fire resistance of all materials used in the containment structure and reactor compartment having regard to normal operating conditions and defuelling.

Fire protection facilities provided in the containment structure and the reactor compartment are to be submitted for approval. These are to provide equivalence with the requirements of Chapter F of the Rules.

308 The provision and location of all spare equipment for nuclear components is to be detailed.

309 At least two independent means of charging coolant into the primary system are to be provided.

#### Reactor Core

310 A specification of all materials proposed for use in the core structure is to be submitted for approval.

311 The data and calculations utilized in the core design are to be submitted for approval.

Where necessary, adequate safeguards must be provided to prevent any dangerous chemical reaction between reactor materials and air or water.

312 The mechanical design, dimensional integrity and manufacturing tolerances of the core structure are to be submitted for examination and approval. Where applicable, the possible relative movement between neutron absorber control material and the core is to be assessed.

313 All possible normal and abnormal reactor transients are to be evaluated and their effect upon the dimensional stability and strength of the reactor core support structure is to be assessed.

314 It is recommended that all reactor pressure vessel internals are to be capable of being dismantled and removed from the pressure vessel. Proposals are to be submitted for consideration.

315 The core structure and fuel assembly are to be capable of withstanding shock and impact loading, *see* R (C) 109 and R (C) 522.

316 The expected change of the physical and chemical properties of the materials proposed for use in the fuel assembly, with irradiation, are to be submitted for approval.

317 The design of the fuel assembly and the operating criteria upon which the design is based are to be submitted for examination. All possible transient conditions (*see* 313) must be examined and related to possible fuel element failure. Experimental evidence of the mechanical strength of the fuel assembly resulting from transient conditions should be provided where possible.

318 The concentration and composition of fission products in the fuel at the end of the designed core life are to be assessed assuming a final period of 100 hours full-power operation.

319 The evidence upon which the fuel element dimensional stability has been assessed including, where possible, previous reactor experience with the proposed fuel assembly up to the full proposed design irradiation is to be submitted for examination.

320 The consequences of salt water contamination of the primary coolant and the corrosion rates of the fuel assembly materials in coolant and in sea water are to be determined.

321 An analysis of the consequences of complete loss of coolant flow with and without control action is to be provided.

322 An analysis of the consequences of staggered loss of coolant flow with and without control action is to be provided.

323 An analysis of possible events leading to and resulting from the sudden introduction of cold coolant into the reactor core is to be provided.

324 The influence of random variations in moderator composition is to be examined.

325 An analysis of the consequences of a restriction of coolant flow in a fuel assembly is to be provided.



326 Each main coolant circuit must be provided with an independent means of circulating coolant. A single loop reactor system must be provided with a minimum of two main coolant circulators. It is recommended that a spare pump unit be carried.

327 Alternatively, if natural convection is proposed as a sole means for primary coolant circulation, proposals are to be submitted for consideration.

328 An analysis of the consequences of leakage of primary coolant and associated loss of pressure with and without control action is to be provided.

#### Decay Heat Removal

329 The arrangements to remove decay heat from the core under normal shut-down conditions are to be submitted for approval. Data, together with method of calculation, is to be provided showing the assessment of variation of decay heat with time.

330 Means are to be provided to remove sufficient decay heat from the core to prevent gross melting and distortion of the core following upon loss of all normal coolant.

331 Facilities are to be provided to permit the testing so far as practicable of all decay heat removal equipment both prior to operation of the reactor and during normal operation to the extent necessary to demonstrate the immediate availability of the systems.

332 Where a single loop circuit is proposed, a decay heat removal system independent of the main coolant loop is to be provided.

333 Facilities, independent of normal electrical power supplies, are to be provided to remove decay heat from the core at angles of list up to 50°.

It should be assumed that the ship lists to 20° instantaneously and that the list continues to increase at the rate of 20° per hour.

#### Section 4

##### REACTOR CONTROL

##### General Requirements

401 The proposed procedures for start-up and normal and emergency plant operation are to be submitted for approval.

402 The design of the control arrangements and any associated mechanism and the power supply to such

mechanisms are to be submitted for approval. Evidence of operational reliability and proposed cycling tests to prove reliability are to be indicated.

403 The physical and chemical properties of materials used in control rod and associated mechanisms are to be submitted for approval. Corrosion rates of control equipment in reactor environment and in sea water are to be determined.

404 The control arrangements are not to move out of the core under gravity, under the force of coolant flow, shock loads or ship movement.

405 A degree of operator adjustment of the control arrangements is to be possible. Protection against possible operator error is to be provided.

406 The normal full-power operating temperatures of control rods are to be determined and the maximum temperature obtaining with one rod stuck in the core is to be determined, together with consequential effects.

407 The maximum insertion and withdrawal rate of any form of control is to be stated and related to possible reactor instability.

408 The consequences of continuous control rod withdrawal at start-up and full power are to be calculated.

409 The control equipment and its associated mechanisms when supported in their environment are to be capable of withstanding shock and impact loading, *see* R (C) 109 and R (C) 522.

410 The control arrangements are to be capable of operation at all ship angles and in the event of power failure must fail safe.

411 A margin of control should be completely withdrawn prior to criticality. The reduction of reactivity effected due to insertion of this margin at full power, at start-up and at all stages of core lifetime should be stated.

412 An alternative method of shutting down the reactor which is not affected by structural distortion of the core is to be provided, e.g. dumping of the moderator or change in moderator mixture or added poison. The time required to operate the system is to be stated.

Calculations or experiments supporting the design of the chosen system should be submitted for appraisal.

413 The plant parameters and the analysis of transient conditions under which emergency shut-down will be initiated are to be submitted for appraisal.



414 Emergency shut-down of the reactor must be implemented at the following ship conditions:—

- (a) 50° list.
- (b) Flooding of the containment.

415 The method proposed to pressurize the primary circuit is to be submitted for approval.

#### Instrumentation

416 Control instrumentation and supplies are to be defined so as to meet control requirements and fault conditions. The instrument response to reactor transients is to be demonstrated.

417 All nuclear instrumentation, including health physics monitoring equipment, is to be described, and its accuracy, reliability and range of operation demonstrated.

418 The method and extent of duplication of essential nuclear instrumentation and supplies is to be stated.

It is required that failure of any item of equipment in any channel shall result in a non-safe indication from that channel. Provision to test each channel without loss of reactor protection is to be possible.

419 All instrumentation relating to the reactor and the reactor compartment is to be described and the range of operation demonstrated.

420 Basic reactor safety instrumentation at the central control position and at the emergency shut-down position must be adequately shock mounted to ensure accuracy and reliability (see R (C) 109 and R (C) 522).

### Section 5

#### COMPLEMENTARY INSTALLATION REQUIREMENTS

##### Major Accidents

501 A containment vessel or structure is required that encloses all primary coolant circuits, and the design of this is to be related to a pressure resulting from a major accident. This accident should be based on an appreciation of the particular reactor design and is to include:—

- (a) Examination of possible nuclear transients contributing to the energy content of the primary circuit.
- (b) Assumption of complete severance of a main coolant pipe or equivalent failure occurring at

working pressure and resulting in discharge of primary coolant into the containment.

- (c) Assumption that failure of the secondary circuit discharges a proportion of the secondary fluid into the containment.
- (d) Consequent exothermic chemical reaction which might result from core melt-down.

502 A pressure/time curve and temperature/time curve of the containment vessel contents covering the first 24 hours after the accident are to be submitted for examination, together with relevant calculations. In addition, the provision to prevent molten fuel penetrating the containment is to be indicated. Where "vapour suppression" or other such means of attenuation of the pressure rise following an accident are proposed, full details are to be submitted at an early stage in the design, together with evidence of their effectiveness.

503 An assessment is to be made of possible damage to the containment structure by missiles produced as a consequence of a component failure inside the containment.

504 A summary of credible accidents covering each particular installation and indicating the degree of hazard involved is to be submitted for consideration. This summary must include a schedule of containment penetrations detailing methods of closure.

##### Shielding

505 Radiation contours in and around the hull, together with method of determination, are to be submitted for approval. Such contours should be determined for full-power operation, shut-down, drydocking, defuelling and after the major accident which invokes the use of containment.

506 In general, designers should work to the recommendations of the International Commission of Radiological Protection so that crews do not receive an integrated radiation dose in excess of 5 rem per year. When the integrated dose is calculated the possible need for maintenance work in high irradiation areas must be considered and it is recommended that 40 per cent of the total dose be reserved for this purpose.

507 The design of primary and secondary shielding, together with their siting and method of securing in the hull structure, are to be submitted for approval. Where necessary, arrangements for shield cooling and ventilation are to be indicated. Adequate periodic examination of the parent structure must be possible.



**Start-up**

508 Sufficient power, independent of the reactor, is to be available to permit start-up of the reactor with any one generator out of action, while maintaining essential services to the ship.

**Defuelling and Refuelling**

509 The arrangements for reactor shut-down for maintenance purposes and immediately prior to defuelling are to be submitted for approval.

510 Removal of a fuel assembly from the core into a container is to take place in such a manner that there will be no hazardous release of fission products to environment. The reactor core is to be in a containment of agreed design at all times. In addition, irradiation hazards to personnel are to be limited and should not exceed the maximum dose rates as recommended by the International Commission of Radiological Protection.

511 The fuel container is to be capable of being cooled and the consequences of failure of cooling are to be examined. The method of cooling and any related design of coolant circuit are to be submitted for approval.

512 The design of fuel containers is to be related to an approved maximum pressure and temperature to which they may be subjected, and the leak rate of the containers under such conditions is not to exceed 0.1 per cent per 24 hours of the gaseous volume of the container loaded with a fuel assembly.

**Effluent Disposal**

513 The facilities provided on board for the storage of radioactive material obtained from the reactor systems and the method proposed for the removal and the subsequent storage ashore is to be submitted for approval.

Arrangements for containment, storage and disposal of radioactive material are to be such that any hazard created by the operation of the ship at sea or in port does not exceed accepted standards having regard to the environmental conditions.

514 In general, containment of all solid and liquid effluents is required and the design of equipment used to effect such containment for a period of 3 months full-power operation and to permit its controlled discharge is to be submitted for approval.

Temporary storage and controlled discharge of innocuous concentrations of gaseous effluent is acceptable, subject to meeting National and International requirements.

Adequate monitoring devices for solid, liquid and gaseous effluent must be provided in all instances.

515 The designs and proposed method of operation of air circulating, air conditioning or air purging equipment in the containment structure are to be submitted for approval. The capacity of the equipment is to be related to the net volumes of the compartment and is to permit complete processing of such volumes in 30 minutes. All air before discharge is to be passed through a fission product clean-up unit.

**Electrical Installations**

516 Electrical installations are to be in accordance with Chapter M and, in addition, with the following Rules.

517 Limits of voltage and/or frequency between which equipment will operate satisfactorily are to be stated.

518 The electrical installation is to be such that failure of any component (e.g. generators, motors, busbars, protective devices or cables) does not interrupt the supply to services essential for the safety of the ship.

519 Emergency supplies in the event of reactor shut-down and/or failure of main supplies must be stated.

**Secondary Circuit**

520 Secondary circuit equipment and machinery, other than primary and secondary heat exchangers, are to conform with the Society's Rule requirements. Power must be available to permit normal manoeuvring of the ship, and the flexibility of the system is to be shown to accommodate all variations in main engine demand.

The reactor transients under such conditions are to be submitted for examination.

**Emergency Propulsion**

521 Unless two or more reactors capable of independent operation are fitted, an independent power supply separate from and independent of the nuclear machinery must be available. The power output of such machinery is to be sufficient to maintain a speed of not less than the minimum required for the ship type and the sea conditions, but in any case not less than 6 knots.

A range of 1600 kilometres is recommended.

**Shock**

522 All reactor components are to be capable of withstanding an impact or shock acceleration of 3 g acting for a perceptible period of time in any direction using the yield stress or proof stress of the materials as a strength criterion.



**Cleanliness**

523 A high standard of cleanliness is to be maintained during construction of reactor components and their assembly into a hull. The methods and techniques required to obtain such a standard are to be submitted for approval.

**Section 6****SURVEY AND MAINTENANCE**

601 All proposed procedures for servicing and maintenance are to be included in the Operations Manual which is to be submitted for examination.

602 Hull and main machinery shall be subject to normal survey requirements.

603 All machinery used directly in conjunction with the reactor shall normally be subject to survey at 4-yearly intervals, or at each refuelling period, whichever is the shorter.

604 The survey requirements for Category "A" pressure vessels and components will be given special consideration for each installation proposed.

605 The main steam generators and associated components in the containment which fall in Categories "B" and "C" (see R (C) 201), together with supports and seatings, shall be subject to survey at 4-yearly intervals or at each refuelling period, whichever is the shorter.

606 Containment structures and supports are to be subject to survey at 4-yearly intervals, and a leak test is to be carried out at that time or in the event of minor modification or repairs to the pressure envelope. The leak test is to be carried out at 50 per cent of the major accident pressure, or at a lower agreed figure provided a leak rate/pressure curve has been determined.

607 An air test to the design pressure is to be carried out on a containment structure whenever a major modification or repair to the pressure envelope is made, or when significant deterioration of the envelope is noted.

608 Double bottom structure external to and in way of the containment vessel shall be subject to survey at 4-yearly intervals or at each refuelling period, whichever is the shorter.

609 Primary and secondary shielding, together with associated parent structure, shall be subject to survey at 4-yearly intervals or at each refuelling period, whichever is the shorter.

610 The design of the reactor installation should permit maintenance work, servicing and inspection to be carried out without excessive exposure of personnel to radiation hazards, which should not exceed permissible dose rates as laid down by the International Commission of Radiological Protection.

611 Containers for radioactive material are to be subject to examination by the Society's Surveyors at 2-yearly intervals except that, where chemical decontamination is used or other severe conditions obtain, it may be required that more frequent examinations be effected.





## R (D) GUIDANCE NOTES ON METAL PIPES FOR WATER SERVICES

Section 1

## PIPES FOR SEA WATER SERVICES

## Types of Corrosion

101 The following types of accelerated corrosion have arisen with piping materials for sea water services:—

- (a) Galvanic corrosion of the less noble metal where dissimilar metals were in association.
- (b) Pitting corrosion, the main causes being local attack by deposits or transfer of small pieces of metal such as weld spatter, sulphides in polluted estuarine waters, gassing in hot tubes of coolers, fouling and cathodic films in the bores of pipes as a result of incorrect methods of manufacture or fabrication.
- (c) Corrosion-erosion where water speeds are excessive for particular metals. This may be particularly severe where turbulence occurs, e.g. protrusions in pipe bores, tight bends.
- (d) Dezincification of some types of brasses including "manganese bronze".
- (e) Stress corrosion cracking of copper-zinc alloys.
- (f) Severe local corrosion due to sulphur and/or sulphide contamination of pipes.
- (g) Cavitation erosion where water speeds are very high.
- (h) Rusting of steel pipes when no protection has been applied or where protection has proved insufficient due to manufacturing fault or damage.

102 Metals differ in their resistance to these various forms of corrosion but even where corrosion resistant types have been used, inadequate attention to design detail or workmanship has caused failures. The following are recommendations for the selection of materials and practices.

## Materials for Pipes and Flanges

103 Steel pipes should be protected against corrosion. Galvanizing of the bores is the most common practice and is recommended as the minimum protection. All steel pipes of bilge and ballast lines should be galvanized.

Galvanized steel pipes should not be used for continuous service where water speeds exceed about 3 m/sec.

The life of a galvanized coating depends on its thickness which to some degree is controlled by pipe thickness. In some cases, it may be advisable to use a pipe of heavier gauge. Welds should be free from lack of fusion and crevices. Where possible, the surfaces should be dressed to remove slag and spatter and, where possible, this should be done before galvanizing. Preferably the coating should be continuous round the ends of the pipes and on the faces of flanges.

104 Rubber-lined steel pipes can give excellent service. The lining is resistant to all forms of corrosion and is particularly effective against scouring by sand. A good bond between the rubber lining and the steel of the pipe is essential. Preferably the rubber lining should be carried round the ends of the pipe and over the faces of the flanges to act as jointing material. There should be no discontinuities or pinholes in the lining, through which corrosion can occur and lift the coating. For these reasons rubber linings should be applied by specialist firms and care taken to avoid damage to finished coatings.

The foregoing comments also apply to plastic-lined pipes. Pipes with stoved coatings are also efficient, but care should be taken to avoid mechanical damage to flanges.

Coatings of the above types should be applied on completion of fabrication, i.e. forming and welding of steel pipes.

105 Copper pipes are particularly susceptible to perforation by corrosion-erosion. These pipes have given the greatest trouble in sea water systems. In some cases copper pipes have been replaced by galvanized steel pipes which have given superior performance.

The cause of the failures of copper pipes has been due mainly to the continuation of an established practice over a period when water speeds have increased appreciably. Low water speeds should be used with copper pipes and excessive local turbulence should be avoided.

106 Certain copper alloys have enhanced resistance to impingement attack and can be used where water speeds are higher than can be tolerated by copper. These alloys are as follows:—

- Copper—30 per cent Nickel—0.8 per cent Iron Alloy.
- Copper—10 per cent Nickel—2 per cent Iron Alloy.
- Aluminium Brass.
- Admiralty Brass.
- Copper—5 per cent Nickel—Iron Alloy.



In general, aluminium brass pipes and tubes give reliable service with reasonably clean sea water. For service with polluted river or harbour waters copper-nickel-iron alloy pipes and tubes are preferable. The nickel content of the alloy for these conditions should not be less than 10 per cent. New copper alloy pipes should not be exposed initially to polluted water. Reasonably clean sea water should be used first in order that the metals can develop protective surface films.

107 Austenitic types of stainless steel are not recommended as they are prone to deterioration when in contact with polluted waters.

108 Where pipes are exposed to sea water on both external and internal surfaces, flanges should be made preferably of the same material. When sea water is confined to the bores of pipes the material of the flange is of less importance from the point of view of corrosion. However, flanges of the same or a less noble metal than that of the pipe, are recommended. Gunmetal flanges on aluminium brass pipes are an exception to this recommendation. Brass for flanges should be of the type containing 1,0 to 2,0 per cent tin to minimize dezincification.

109 Fixed or loose type flanges may be used. The fixed flanges should be attached to the pipes by fillet welds or capillary silver-brazed joints as appropriate. Where welding is used, the fillet weld at the back should be a strength weld and that in the face a seal weld.

Where silver-brazing is used, strength should be obtained by means of the bond in a capillary space over the whole area of the mating surfaces. A fillet braze at the back of the flange or at the face is undesirable.

A combination of a silver-brazed joint at the front face and a normal brazed joint at the back face has given satisfactory service when the bore surface only was exposed to sea water.

110 With copper-nickel-iron alloy pipes, flanges of a similar type of alloy or of mild steel may be attached by argon arc welding. A mild steel flange should not be used when it will be in contact with sea water.

Copper, brass, bronze, gunmetal or copper-nickel-iron alloy flanges may be capillary silver-brazed to copper, aluminium brass or copper-nickel alloy pipes. "Bronze welding" should not be used. Brazing of inhibited alpha brass flanges to copper pipes using rods of a 92,75 per cent copper-7,25 per cent phosphorus alloy has given satisfactory service. The alloy used for silver-brazing should contain not less than 49 per cent silver.

Mild steel flanges should be fusion welded or flash butt welded to mild steel pipes.

111 Alpha brasses must be properly inhibited against dezincification by suitable additions to the composition. Alpha-Beta brasses or those containing less than 70 per cent copper should not be used for pipes and fittings.

#### Design Considerations

112 In sea water, galvanic corrosion may cause premature failure of a component when it is in contact with one of a more noble metal. For guidance, Table R(D) 1.1 gives the galvanic series for common metals in sea water. A metal in direct contact with one lower in the list may suffer accelerated corrosion in sea water.

TABLE R(D) 1.1

#### GALVANIC SERIES IN SEA WATER

Zinc  
Aluminium  
Carbon Steel  
Cast Iron  
Lead-Tin Solders  
Lead  
Brasses  
Copper  
Phosphor Bronze  
Gunmetal  
Copper-Nickel-Iron Alloys  
Aluminium Bronze  
Monel Metal

Where components are made from different metals, preferential corrosion of the less noble metal may be minimized by the introduction of a sacrificial anode. This is made of a metal which is higher in the Table than either of the working metals. Where a sacrificial anode is used to provide local protection, there should be an efficient electrical bond between it and the metal which it is to protect.

113 Water speeds should be carefully assessed at the design stage and the materials of pipes, valves, etc. selected to suit the particular conditions.

114 Attention should be given to the design, fabrication and installation of systems to ensure streamlined flow. In particular, abrupt changes in the direction of flow, protrusions into bores of pipes and other restrictions of flow should be avoided.

Pipe bores should be smooth and clean. Any carbonaceous films or deposits formed on the bore surfaces of non-ferrous pipes during bending processes should be carefully removed. Jointing should be flush with the bore surfaces of the pipes. Branches preferably should be set at a shallow angle to the line of the main piping, the junction should be smooth and the branch should not protrude into the bore of



the main pipe. Tight bends should be avoided. The bore surfaces should be smooth at these positions and free from puckering.

115 Very low water speeds and stagnant zones should be avoided. Systems should not be left idle for long periods especially where the water may be polluted.

116 Strainers should be provided at the inlets to sea water systems.

117 Non-ferrous pipes which are fairly heavily cold worked during fabrication should be annealed or stress relief heat treated before they are put into service. Finished aluminium or Admiralty brass pipes, in particular, should not be overstrained to facilitate alignment and tight joints.

## Section 2

### PIPES FOR FRESH WATER SERVICES

201 The corrosive conditions in fresh water systems are less severe than in sea water systems and generally mild steel or copper pipes are satisfactory for service in fresh water applications.

202 Mild steel pipes should not be left idle for long periods if the water has a low salt content. This low salinity and the limited supply of oxygen promote the formation of black iron oxide on the bores of the pipes which gives rise to severe corrosion of the pipes. Where stagnant conditions are unavoidable steel pipes should be galvanized or pipes of suitable non-ferrous material should be used. Hot fresh water may promote corrosion of mild steel pipe unless the hardness and pH of the water are controlled.

203 Copper alloy pipes should be treated by scouring or other means to remove any harmful cathodic films from the bores before pipes and tubes are despatched from the makers' works.

204 Brass fittings and flanges in contact with water should be made of an alpha brass which is inhibited against dezincification.

205 Aluminium brass pipes and fittings are not recommended for fresh water services as, under certain circumstances (not yet completely defined), premature failure by pitting and/or cracking can occur.





## R (E) GUIDANCE NOTES ON TORSIONAL VIBRATION CHARACTERISTICS OF MAIN AND AUXILIARY OIL ENGINES

### Section 1

#### TORSIONAL VIBRATION CRITICAL SPEEDS AND LIMITING VIBRATION STRESSES

##### General

**101** In oil engine installations torsional critical speeds occurring between idling and full speeds are generally inevitable and these guidance notes are intended to safeguard machinery from the effects of excessive torsional vibration during the life of the ship.

The stress limits recommended provide reasonable margins to avoid shaft fatigue failure. Critical speeds at which the stress limits would be exceeded, should be avoided for continuous operation.

Careful attention, however, should be given to the dynamic system at the design stage to ensure, in particular, that significant critical speeds requiring "barred" ranges are avoided within the speed range(s) proposed for continuous operation in service. See 104, "Barred" Speed Ranges.

The stress limits set out in the following paragraphs should not be viewed necessarily as design values, but rather as values which should not be exceeded where critical speeds of appreciable importance cannot reasonably be avoided.

The stresses considered in these notes are nominal values based on the plain section of the shafting, excluding stress raisers.

Between 90 and 100 per cent of the maximum continuous speed, the stress limits apply to the sum of the vibratory stress due to any resonant order and stresses due to the dynamically magnified portions only of the flanks of other significant orders (i.e. subtracting the stresses due to the exciting torques).

Where critical speeds are found by calculation to show stresses approaching the limits, torsionograph records may be required. In practice, differences between calculated stresses and stresses measured by torsionograph or equivalent are frequently found. Where such differences arise, the stress limits are to be applied to the measured stresses.

The stress limits are applicable to steel shafts having a tensile strength of 430 to 510 N/mm<sup>2</sup> (44 to 52 kgf/mm<sup>2</sup>). For shafts of higher tensile steel or other material, the stress limits will be subject to special consideration.

Where the scantlings of crankshafts, webs, couplings, coupling bolts and straight shafting are greater than required by the Rules, higher vibratory stress limits may be considered.

##### Engine Speed—Revolutions per Minute

**102** Maximum continuous speed  $N_S$  may be defined as the maximum revolutions per minute for which the engines are classed in continuous operation.

In the case of constant speed generating sets for main propulsion or auxiliary purposes  $N_S$  is taken as the full load revolutions per minute.

Any special speed requirements for prolonged periods in service should be indicated, e.g. range of trawling revolutions per minute, range of operating revolutions per minute with controllable pitch propeller, idling revolutions per minute, etc. Such speed ranges should be maintained clear of significant critical speeds so far as practicable.

##### Governor Control

**103** For closely governed installations, the application of formulae 110 (4) and 111 (4) may be restricted to speeds 5 per cent higher than the governor control limit, with a minimum of 1.10  $N_S$ , provided such limit be demonstrated during engine trials.

##### "Barred" Speed Ranges

**104** Where restricted speed ranges are imposed as a condition of approval, a notice board is to be displayed at the control station(s) stating that continuous operation should be avoided between the limits indicated by formulae 110 (2) and 111 (2), and the tachometers marked accordingly. In such cases the tachometer accuracy should be checked against the counter readings, or by equivalent means, in the presence of the Surveyors to verify that it reads correctly within  $\pm 2$  per cent in way of the restricted range of speeds.

Where vibration stresses due to criticals below 0.8  $N_S$  marginally exceed the limiting stress for continuous operation, or where the critical speeds are sharply tuned, the range of speeds restricted for continuous operation may be reduced.

Where such vibration stresses approach the limiting values  $f_t$  given in formulae 110 (3) and 111 (3) the range of speeds restricted for continuous operation may be extended, and the notice board(s) should indicate that this range must be passed through rapidly.

In cases where the resonance curve of a critical speed has been derived from torsionograph measurements, the range of speeds to be avoided for continuous running may be



taken as that over which the measured vibration stresses are in excess of the limiting stresses for continuous operation, having regard to the tachometer accuracy.

#### Excessive Vibration Stresses

105 In cases where vibration stresses exceed the limiting values, the dynamic system should be re-designed, or damping or detuning arrangements provided to remove the critical speed from the operating range or to reduce the magnitude of the vibration stress.

It is preferable to avoid the use of dampers or detuners to control criticals within the range between 0,85 and 1,05  $N_S$ , but if fitted they should be of a type which makes adequate provision for dissipation of heat and contain no mechanical parts subject to deterioration in service.

Where dampers or flexible couplings are fitted, it may be required that torsigraph records be taken to verify their efficacy.

#### Gear Hammer

106 In installations having reversing and/or reduction gearing, or geared scavenge blowers, etc., where the vibratory torques at the gears exceed the mean transmission torques at the criticals considered, it may be necessary to impose a restricted range of speeds in way of each critical speed at which gear hammer occurs.

Further, in the event of gear hammer being detected at speeds other than the calculated critical speeds, torsigraph records may be required to confirm the calculated natural frequencies.

In all cases where there is a possibility of gear hammer, the backlash in the gears should be kept to a minimum.

At critical speeds near the maximum speed the vibratory torque should not, in general, exceed one-third of the full transmission torque. In cases where the proposed loading on the gear teeth is less than the maximum allowable special consideration will be given to the acceptance of additional vibratory loading on the gears.

#### Screwshafts

107 The stress limits for screwshafts apply to fully protected shafts having a continuous liner with efficient sealing arrangements against corrosion of the shaft by sea water, and to shafts without liner which are oil lubricated and which are fitted with an approved type of oil gland.

In other cases special consideration will be necessary.

The limits are intended to apply to the minimum section of the shaft between the forward end of the propeller boss and the forward stern gland.

#### Intermediate Shafts

108 The stress limits for intermediate shafts apply to shafts having integral flanges with Rule fillet radii.

Where loose couplings are employed, the vibration stresses in the shaft in way of the coupling should be limited to 75 per cent of these values.

#### Definition of Symbols

109 In the formulæ for determining vibration stresses, the symbols used are as follows:—

$N$  = engine speed, rev/min,

$N_S$  = maximum continuous engine speed, rev/min (see 102),

$N_C$  = critical speed, rev/min,

$r$  = ratio  $N/N_S$  or  $N_C/N_S$  whichever is applicable,

$d$  = minimum shaft diameter considered, in mm,

$f_c$  = maximum value of the vibration stress for continuous running at or below  $N_S$ , in  $N/mm^2$  (kgf/cm<sup>2</sup>),

$f_t$  = maximum value of vibration stress due to criticals below 0,8  $N_S$  necessitating restricted ranges, in  $N/mm^2$  (kgf/cm<sup>2</sup>),

$f$  = maximum value of the vibration stress above  $N_S$ , in  $N/mm^2$  (kgf/cm<sup>2</sup>).

#### Propelling Machinery—Vibration Stress Limits

##### Crankshafts and Screwshafts

110 Where the critical occurs at or below the  $N_S$ , vibration stresses not exceeding values given by the following formula are considered satisfactory for continuous running:—

$$f_c = \pm (30,9 - 0,0216d) (1,6 - r^2) \quad (1)$$

$$(f_c = \pm (315 - 0,22d) (1,6 - r^2))$$

Where the vibration stresses exceed the limiting values for continuous running as given by formula (1), a notice board should be fitted at control stations stating that the engine should not be run continuously between the following speed limits, above and below the critical speed, and the engine tachometers should be marked correspondingly:—

Range of engine rev/min to be avoided:—

$$\text{From } \frac{16 N_C}{(18-r)} \text{ to } \frac{(18-r) N_C}{16} \text{ inclusive} \quad (2)$$

The maximum values of the vibration stresses due to such criticals should not exceed those given by the following formula:—

$$f_t = 2 f_c \quad (3)$$

Criticals should be arranged sufficiently removed from  $N_S$  to ensure that, in general, at  $r = 0,8$  the stress due to the upper flank does not exceed  $f_c$  (formula (1)).



Where the critical occurs above the  $N_S$ , the vibration stresses should not increase beyond values given by the following formula at speeds up to 1,16 times  $N_S$ :—

$$f = \pm (18,63 - 0,0127d) (1 + 5\sqrt{r-1}) \quad (4)$$

$$(f = \pm (190 - 0,13d) (1 + 5\sqrt{r-1}))$$

#### Intermediate and Thrust Shafts

111 Where the critical occurs at or below  $N_S$ , vibration stresses not exceeding the values given by the following formula are considered satisfactory for continuous running:—

$$f_c = \pm (52,47 - 0,0216d) (1,44 - r^2) \quad (1)$$

$$(f_c = \pm (535 - 0,22d) (1,44 - r^2))$$

Where vibration stresses exceed the limiting values for continuous running as given by formula (1), a notice board should be fitted at control stations stating that the engine is not to be run continuously between the following speed limits, above and below the critical speed, and the engine tachometers should be marked correspondingly:—

Range of engine rev/min to be avoided:—

$$r \text{ from } \frac{16 N_C}{(18-r)} \text{ to } \frac{(18-r) N_C}{16} \text{ inclusive} \quad (2)$$

The maximum values of the vibration stresses due to such criticals should not exceed those given by the following formula:—

$$f_t = 1,7 f_c \quad (3)$$

Criticals should be arranged sufficiently removed from  $N_S$  to ensure that, in general, at  $r = 0,8$  the stress due to the upper flank does not exceed  $f_c$  (formula (1)).

Where the critical occurs above  $N_S$  the vibration stresses should not increase beyond values given by the following formula at speeds up to 1,16 times  $N_S$ :—

$$f = \pm (23,05 - 0,0095d) (1 + 5\sqrt{r-1}) \quad (4)$$

$$(f = \pm (235 - 0,097d) (1 + 5\sqrt{r-1}))$$

#### Auxiliary Machinery and Propulsion Oil Engine Driven Generators

112 The following notes are applicable to oil engines developing 100 kW (150 shp) and over, driving auxiliary machinery used for essential services and to propulsion oil engine driven generating sets operating at constant speed.

The dynamic system comprising engine and driven machinery should be so designed that vibration stresses in the crankshafts and transmission shafting resulting from critical speeds do not exceed values given by the following formula within speed limits of 0,95 and 1,10  $N_S$ ,  $N_S$  being the full load rev/min:—

$$f_c = \pm (20,79 - 0,0137d) \quad (1)$$

$$(f_c = \pm (212 - 0,14d))$$

Vibration stresses in the crankshaft and transmission shafting due to critical speeds which have to be passed through in starting and stopping should not exceed values given by the following formula:—

$$f_t = 5,5 f_c \quad (2)$$

Furthermore, the amplitudes of vibratory inertia torque imposed on generator rotors should be limited to  $\pm 2,0 Q_S$  in general, or to  $\pm 2,5 Q_S$  for close-coupled revolving field a.c. generators, over the speed range from 0,95 to 1,10  $N_S$  and to  $\pm 6,0 Q_S$  in passing through criticals below 0,95  $N_S$ , where  $Q_S$  is the rated full load mean torque.

The rotor shaft and structure should be designed to withstand the foregoing magnitudes of vibratory torque.

Where it can be shown that the generator rotor structure is capable of withstanding a higher vibratory torque than indicated above, special consideration will be given.

Where two or more generators are driven from one engine, each generator should be considered separately in relation to its own designed rated torque.

The total inertia torque acting upon the rotor should be taken into consideration in the speed range from 0,95  $N_S$  to 1,10  $N_S$ . Ideally, the method of calculating the total inertia torque should be consistent with values derived from strain gauge measurements on the rotor shaft. In general, the assessment should be based on forced-frequency calculations (see R (E) 225) taking account of all significant harmonic exciting torques and their relative phases, together with system damping where applicable. As an alternative to the forced-frequency calculations method, the total vibratory torque may be calculated as the arithmetical sum of the vibratory torques due to any resonant order and the non-resonant contributions of all other significant orders, including the first major order. In the case of close-coupled installations, the combined effect of two or more modes of vibration may require consideration when using the alternative method. In marginally acceptable installations, confirmatory measurements may be required.

*For graphs showing permissible vibration stresses for propelling machinery, see Fig. R (E) 1.1*

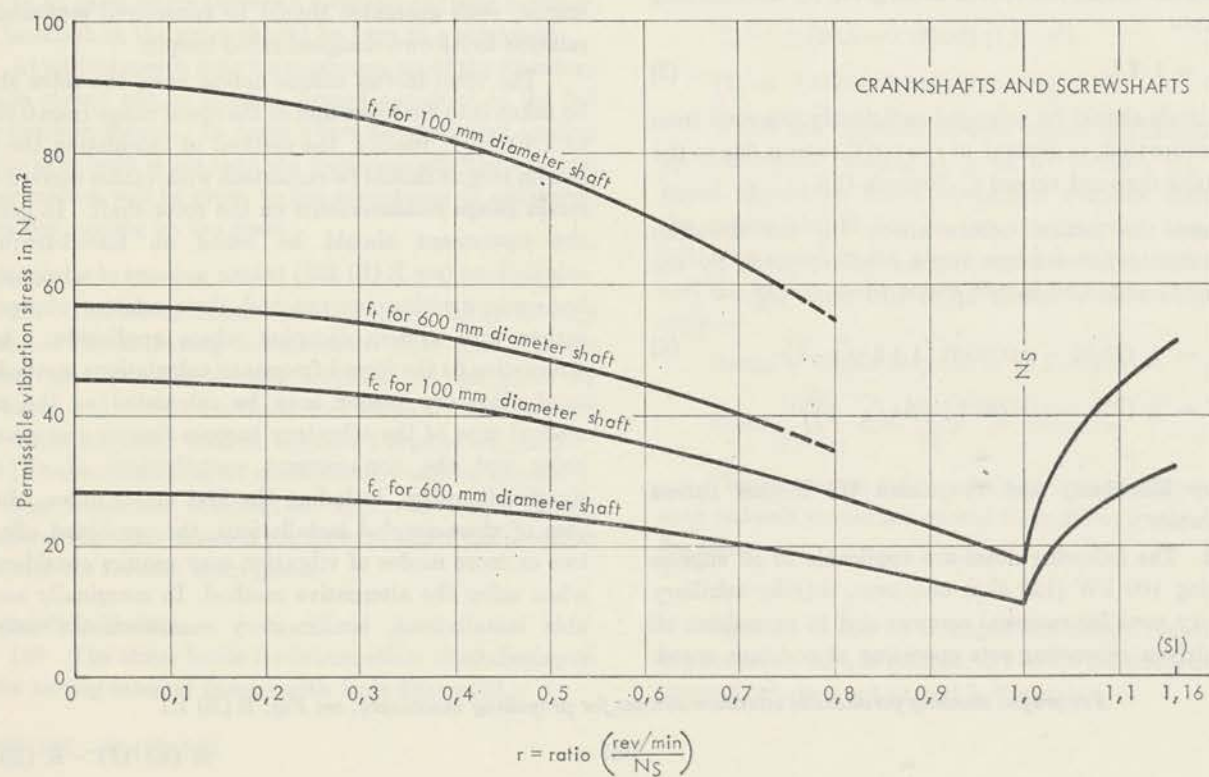
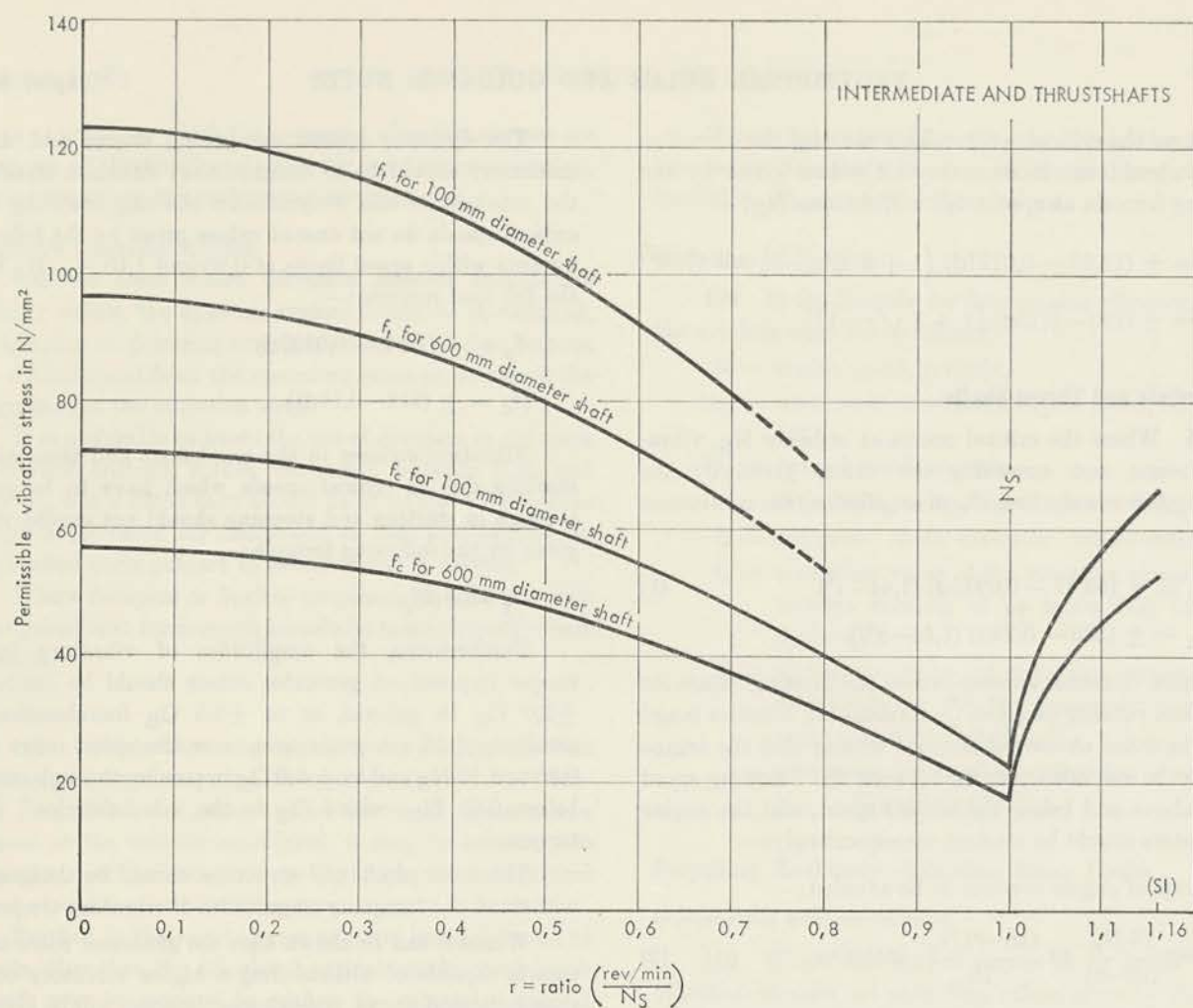


FIG. R (E) 1.1 (SI)

PERMISSIBLE VIBRATION STRESSES FOR PROPELLING MACHINERY



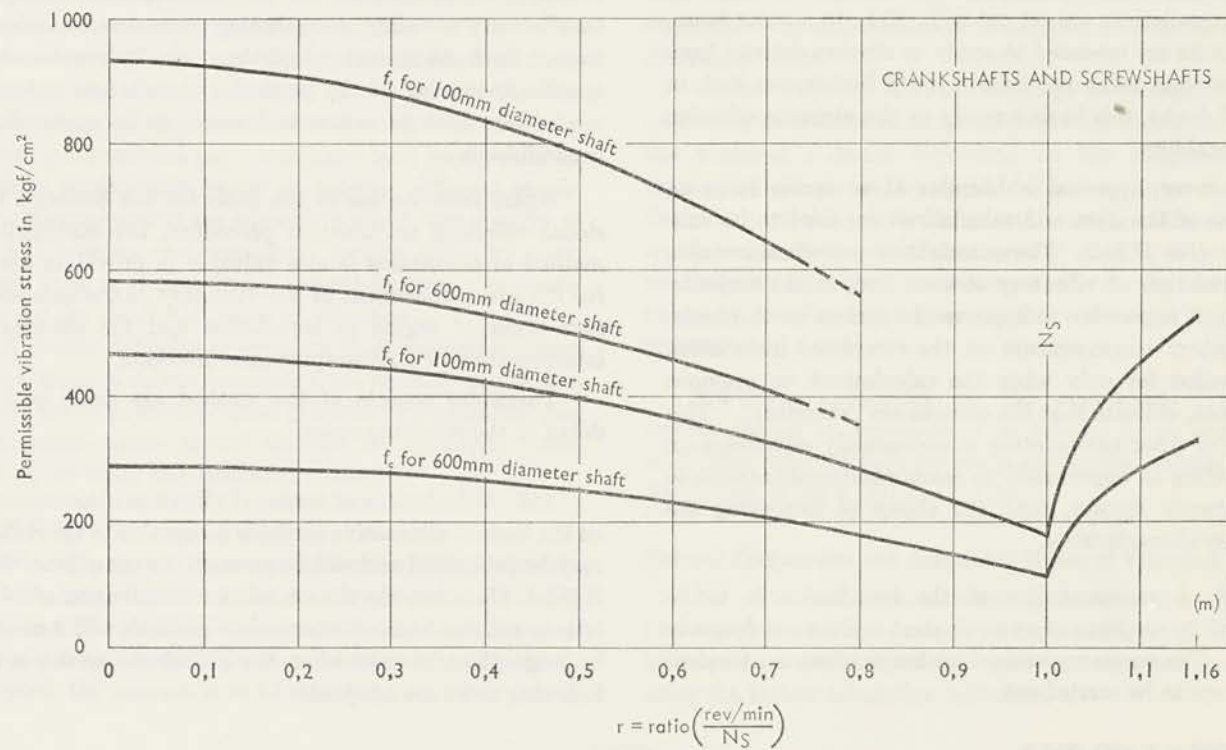
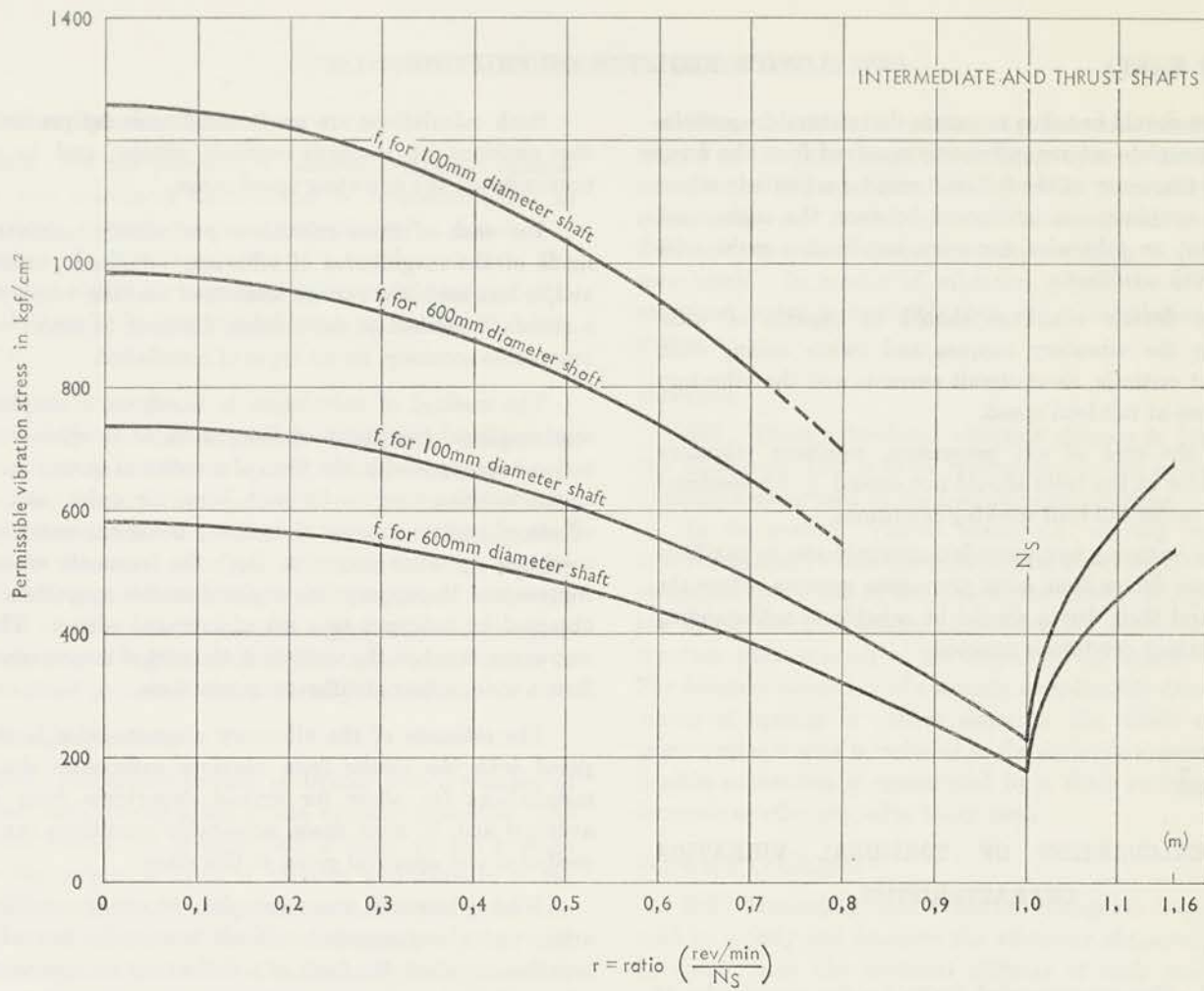


FIG. R (E) 1.1 (Metric)

PERMISSIBLE VIBRATION STRESSES FOR PROPELLING MACHINERY

Care should be taken to ensure that natural frequencies of the complete set are sufficiently removed from the firing impulse frequency at the full load speed, particularly where flexible couplings are interposed between the engine and generator, as otherwise excessive amplitudes could arise under such conditions.

The flexible couplings should be capable of withstanding the vibratory torques and twists arising from transient criticals, short-circuit currents and the vibratory conditions at full load speed.

In the case of a.c. generators, resultant vibratory amplitudes at the rotor should not exceed  $\pm 2.5$  electrical degrees under full load working conditions.

The foregoing recommendations apply also to auxiliary generators driven from main propulsion systems, where the rotors and their drives should be capable of withstanding the vibratory conditions imposed.

## Section 2

### THE CALCULATION OF TORSIONAL VIBRATION CHARACTERISTICS

#### General

**201** The recommended limits for the magnitudes of torsional vibration stresses in the shafting of marine oil engine installations are set out in R (E) 1. In a strict sense, these limits are intended to apply to stresses derived from measurements taken on the completed installation and, in cases of doubt, this basis remains as the ultimate criterion of acceptability.

However, approval is desirable at an earlier stage on the basis of the data and calculations required to be submitted. (See H 242). The examination procedure includes the calculation of vibratory stresses and, in the majority of cases, it is possible to approve the system on this basis, confirmatory measurements on the completed installation being called for only when the calculations, or previous experience, indicate that the stresses are "marginal". This process of prior examination is additionally advantageous in providing an opportunity to recommend modifications to the dynamic system, with the object of improving the vibratory characteristics.

**202** A representation of the installation is to be prepared in the form of an equivalent multi-mass dynamic system. The necessary natural undamped frequency calculations are to be carried out.

Such calculations are used as the basis for predicting the positions of resonant criticals within, and in the proximity of, the operating speed range.

For each of these criticals a preliminary estimate is made of the magnitudes of vibratory amplitude, stresses and/or torques in the various sections of shafting, employing a standard method of calculation, designed to cater, with reasonable accuracy, for all types of installation.

The method of calculation is based on a simplified semi-empirical treatment of the system as a whole, excitation being applied in the form of a vectorial summation of engine exciting torques for each harmonic order, and the effects of various sources of damping being expressed as a combined dynamic magnifier. Both the harmonic exciting torques and the appropriate engine dynamic magnifiers are obtained by reference to a set of averaged curves. These curves are based on the analysis in the past of measurements from a wide variety of different installations.

The estimate of the vibratory characteristics is compared with the results from previous sufficiently similar installations (to allow for typical departures from the average) and, in most cases, acceptable conditions can be predicted and approval given at this stage.

Where, however, more complex vibratory conditions arise, e.g. where resonant criticals cannot be treated in isolation, or where the flank of a critical has an appreciable effect at the maximum continuous engine speed, or in heavily damped systems, the simplified treatment may be insufficiently revealing, necessitating more detailed calculations. Such additional calculations usually require more specific knowledge of the particular installation and vary too widely, both in nature and scope, to be amenable to generalisation.

Apart from its use as the basis for the Society's torsional vibration examination procedure, the standardized method of calculation is also valuable in providing means for the early assessment of the vibratory characteristics of new types of engine or installation and the subsequent interpretation of torsigraphic measurements.

Particular aspects of the method are dealt with in detail in the following notes.

**203** Calculations of torsional vibration characteristics on the basis of alternative methods acceptable to the Society may be submitted and will be assessed for compliance with R (E) 1. However, the time taken for examination of calculations on the basis of alternative methods will normally be longer than for cases where the procedures set out in the following notes are adopted.



### Equivalent Dynamic Systems

204 For the purposes of torsional vibration calculations the machinery installation is represented by an equivalent dynamic system consisting of a number of discrete rigid inertias separated by massless shafts. The equivalent shafts are expressed in terms of torsional stiffness, although the reciprocal form is an acceptable alternative.

### REFERRED SYSTEMS

205 In the case of geared installations, comprising shafts rotating at different speeds, the equivalent dynamic system is referred to the speed of the engine crankshaft, for ease in later calculation. For multi-engined installations, although the basic principles of the method are equally applicable, special considerations associated with the possible variations in the mode of operation and indeterminate phasing of engines, will require some modification to the standard procedure and mode of presentation.

### CRANKSHAFT SYSTEMS

206 The engine system is divided into a number of inertias, each concentrated at the cylinder centreline. The effective inertia per cylinder line is taken as the average value throughout a cycle of rotation and consists of the inertia of all the rotating elements, including balance weights and a portion of the connecting rod, together with the inertia given by one-half of the mass of the reciprocating elements considered concentrated at the crankpin radius. In the case of a "Vee" engine, the inertias for each pair of cylinders are combined into a single inertia.

Accurate estimation of the equivalent shaft stiffness between engine cylinder centres is complicated by the irregular shape of the crankshaft. Numerous formulae for evaluating the stiffness per crank throw have been published and their applicability varies as between different engine types. Enginebuilders are advised to check the validity of their estimates for new crankshaft designs, either by static stiffness tests or indirectly by natural frequency measurements for the crankshaft mode of vibration.

(A similar difficulty in assessing shaft stiffnesses occurs in some types of driven machinery, particularly in the case of rotor shafts in close-coupled generator installations, and experimental means should likewise be employed where necessary to verify the estimated values).

### PROPELLERS

207 It is necessary in estimating the effective inertia of marine propellers to make an allowance for entrained water. In the absence of detailed information, this allowance is taken as 25 per cent. Where a value other than 25 per cent is adopted, the amount is to be stated.

Where controllable pitch propellers are fitted, two sets of calculations, based on dynamic systems having 25 per cent and 10 per cent entrained propeller water allowance respectively are carried out, in order to estimate the difference in natural frequency when working at full and zero pitch. In modes of vibration where the effect of entrained water is negligible, one set of calculations will suffice.

### DAMPERS

208 Where a torsional vibration damper is fitted to the machinery, this is to be represented in the equivalent dynamic system used in the frequency calculations.

In the case of "viscous shear" or "slipping torque" types of damper, where the seismic mass is not mechanically connected to the rest of the system, the damper is represented by an effective inertia comprising the casing or hub, together with one-half of the inertia of the seismic mass. For dampers consisting of a seismic mass flexibly driven by means of springs or rubber elements, the whole of the seismic mass inertia is included in the dynamic system. The flexible connection is represented by a shaft stiffness, the dynamic or effective value being used.

### FLEXIBLE COUPLINGS

209 Torsionally flexible shaft couplings are frequently used to modify and improve the vibratory characteristics. In many cases the torsional stiffness of such couplings varies as between static and dynamic conditions of loading, and, wherever possible, the effective dynamic stiffness as determined by experiment is to be used in compiling the dynamic system.

Certain types of flexible couplings are designed with non-linear or discontinuous torque/deflection characteristics, the torsional stiffness depending on the magnitude of transmitted torque and/or speed of rotation. In such cases, depending on the relative importance and position in the speed range of the significant critical speeds, it may be necessary to calculate natural frequencies on the basis of a range of coupling stiffnesses in the equivalent dynamic system.

210 The particulars of the equivalent dynamic system should be summarized in tabular form, together with other relevant data for use in subsequent calculations. See Tables R (E) 2.1(a) and 2.1(b).

### Natural Frequencies and Associated Modes of Vibration

211 The natural torsional frequencies of the installation together with their associated modal characteristics are calculated on the basis of the equivalent dynamic system, using the Holzer tabulation technique.



The number of modes requiring to be investigated varies as between different installations, but the search should be carried out up to a frequency equivalent to 15 times the maximum continuous speed of the engine. This ensures that it will be possible in later calculations to account for critical resonant conditions arising from all harmonic torque excitations up to order 12, in a speed range extending up to 125 per cent of the maximum continuous engine speed.

**212** The information obtained from the natural frequency calculations for each mode of vibration should be summarized as in Table R (E) 2.2.

The relative amplitude in column 2 of the Table is arranged to have a value of unity at the mass position corresponding to engine cylinder No. 1 (i.e. the cylinder farthest removed from the driven machinery). Consequently the vibratory torques listed in columns 3 and 4 and the shaft stresses in column 6 relate to a modal amplitude of 1 radian at engine cylinder No. 1. From these values of relative amplitude, phasevector sums are calculated and tabulated for all relevant modes. (Table R (E) 2.3). In addition, the stress factors listed in column 6 are corrected for the actual shaft speed, the reduction gear ratio, where applicable, having been taken into account.

#### The Prediction of Vibratory Magnitudes by Calculation

**213** Each torsional mode of vibration having a natural frequency,  $F$  hertz ( $F$  cycles/min), is excited by the harmonic components of the applied torque, the order number of each harmonic being denoted by  $m$ . Resonant conditions associated with these harmonic orders of excitation arise at a series of critical running speeds, given in general by

$$N_c = \frac{60F}{m} \text{ rev/min} \quad \left( N_c = \frac{F}{m} \text{ rev/min} \right)$$

**214** The magnitudes of vibration are to be estimated for all such critical conditions occurring in a speed range extending from 10 per cent up to 125 per cent of the maximum continuous engine speed,  $N_s$ .

For each critical speed,  $N_c$ , considered, the amplitude of torsional vibration,  $\theta_1$ , at engine cylinder No. 1 is given by

$$\theta_1 = \pm M \theta_0 \text{ radians,}$$

where  $M$  = dynamic magnifier for the whole system, (See 217 to 222),

$$\theta_0 = \frac{T_m A R \vec{\Sigma} \Delta}{\omega^2 \Sigma (J \Delta^2)} \text{ radians,}$$

$T_m$  = resultant  $m^{\text{th}}$  order harmonic component of tangential effort at each crankpin, expressed per unit area of piston, in  $\text{N/mm}^2$  ( $\text{kgf/cm}^2$ ), (See 216),

$A$  = area of each piston, in  $\text{mm}^2$  ( $\text{cm}^2$ ),

$R$  = crank radius, or mean crank radius for opposed piston engines, in  $\text{m}$  ( $\text{cm}$ ),

$\vec{\Sigma} \Delta$  = phase-vector sum for all engine cylinders, (Table R (E) 2.3), derived from the frequency table relative amplitudes and the  $m^{\text{th}}$  order phase angle diagram,

$\omega$  = natural phase velocity of the mode of vibration, in  $\text{rad/sec}$ ,

$\Sigma (J \Delta^2)$  = summation of terms, obtained from the natural frequency table (Table R (E) 2.2), for the whole system, in  $\text{kg m}^2$  ( $\text{kg cm sec}^2$ ).

**215** Having calculated the vibratory amplitude,  $\theta_1$ , the corresponding stress in any shaft in the system is obtained by multiplying  $\theta_1$  by the appropriate stress factor in column 6 of the tabulated natural frequency data. (Table R (E) 2.2.)

By a similar process of scaling, magnitudes of vibratory amplitude and torque, where these quantities are of interest, are predicted for any part of the system, making use of the entries in the appropriate columns of the Table.

Thus, for example, in geared installations, predictions relating to the likelihood of vibratory torque reversal, and hence "gear hammer", arising at resonant conditions are based on a comparison between the estimated vibratory torque occurring at the gear mesh and the mean driving torque transmitted at the particular running speed. In this connection, the inertia of the gearing is split into driving and driven components in the natural frequency calculations, thereby permitting a better assessment of the vibratory torque at the actual gear mesh.

As a further example, in the case of generator installations, a comparison is required between the vibratory inertia torque imposed on the armature and the full load mean torque. Here the inertia torque is obtained from the appropriate entry in column 3 of the tabulated data. (Table R (E) 2.2.)

#### Harmonic Torque Components

**216** Figs. R (E) 2.1(a) and 2.1(b) give averaged curves of resultant components of tangential effort ( $T_m$ ) per unit area of piston, plotted against cylinder mean indicated pressures, for each harmonic order,  $m$ .



Although presented in a form suitable for 4-stroke engines, the curves for the integral order harmonics apply equally to 2-stroke engines (including opposed piston engines), the appropriate values being doubled.

Inertia torque components, due to the reciprocating parts, have not been taken into account in these curves and the values used for the first three integral order harmonics require suitable correction in individual cases.

In certain installations it may be necessary to consider excitation from the propeller as well as from the engine.

#### Dynamic Magnifiers

217 Although the method already described for calculating magnitudes of vibration at critical speeds involves the use of a dynamic magnifier applying to the system as a whole, the more important sources of damping are determined individually. The partial dynamic magnifiers so obtained are then combined on an empirical basis to give an overall magnifier for the complete system. (See also 222).

#### ENGINE MAGNIFIER

218 The dynamic magnifier associated with the effects of damping arising within the engine,  $M_E$ , is expressed as a function of  $\theta_0$ ,

$$M_E = 3,8 \theta_0^{-1}$$

For convenience, this expression is given in graphical form in Fig. R (E) 2.2.

In practice, the value of  $M_E$ , so obtained, is limited to a maximum of 50.

In installations where the engine provides the only appreciable source of damping, or in modes of vibration insensitive to damping arising elsewhere, the engine magnifier,  $M_E$ , becomes the effective magnifier,  $M$ , for the whole system.

#### PROPELLER MAGNIFIER

219 Propeller damping, which assumes importance in the case of shafting modes of vibration of propulsion machinery, is taken into account by the use of a propeller dynamic magnifier,  $M_P$ , determined from the following formula:—

$$M_P = \frac{\Sigma (J \Delta^2) N_s^3 m}{91\,200 a H \Delta_p^2}$$

$$\left( M_P = \frac{\Sigma (J \Delta^2) N_s^3 m}{680\,000 a H \Delta_p^2} \right)$$

where

$\Sigma (J \Delta^2)$  = summation of terms for the whole system, in  $\text{kg m}^2$  ( $\text{kg cm sec}^2$ ),

$N_s$  = maximum continuous engine speed, in rev/min,

$m$  = harmonic order number,

$H$  = rated shaft power at the maximum continuous engine speed, in kW (shp),

$\Delta_p$  = relative modal amplitude at the propeller, in radians, (referred to crankshaft speed in the case of a geared installation),

$a$  = coefficient, taken as 30 (average value),

$$= \frac{K_p N_c}{Q_c}$$

where

$K_p$  = propeller damping coefficient, in N m sec/rad ( $\text{kgf cm sec/rad}$ ),

$Q_c$  = mean propeller torque at critical speed, in N m ( $\text{kgf cm}$ ),

$N_c$  = propeller speed at critical, in rev/min.

Where the propeller design is such as to indicate that its damping properties may be other than the average assumed in the above formula and also in the case of a controllable pitch propeller, an appropriate adjustment to the coefficient,  $a$ , may be accepted, based on the geometrical parameters of the propeller, or on the evidence of measured results.

#### VIBRATION DAMPER MAGNIFIERS

220 Vibration dampers in general vary widely in their mode of operation. Assessment of the damping properties of a particular combination of damper and engine system, together with the corresponding equivalent damper magnifier,  $M_D$ , should be carried out in consultation with the damper manufacturers and the predictions verified by practical measurement on a typical installation. See R (E) 105.

In the particular case of a viscous-shear type of damper, the additional damping influence (assumed to be under optimum conditions of tuning) is calculated by taking a dynamic magnifier

$$M_D = \frac{2,0 \Sigma (J \Delta^2)}{J_R \Delta_D^2}$$

where

$\Sigma (J \Delta^2)$  = summation for complete system, including contribution from the effective damper inertia,

$J_R$  = moment of inertia of the seismic mass,

and  $\Delta_D$  = relative modal amplitude at damper casing.



## FLEXIBLE COUPLINGS

221 Many types of flexible couplings, apart from providing convenient means for modifying and improving the natural frequency characteristics of machinery installations, also are designed to have a controlling influence on the systems under resonant conditions, either by the incorporation of true damping principles or by virtue of detuning effects produced by non-linear torque/deflection relationships. This ability to reduce the magnitude of resonant criticals is usually confined to modes of vibration having appreciable relative angular deflections across the coupling elements. The manufacturers should be consulted regarding the appropriate characteristics of the coupling with reference to energy loss/cycle, and for novel types the value assumed is to be confirmed by measurement on a typical installation.

## COMBINED DYNAMIC MAGNIFIER

222 The overall dynamic magnifier,  $M$ , for the system as a whole is obtained by combining the magnifiers, estimated for the individual sources of damping, in the following empirical manner:—

$$M = \left[ \left( \frac{1}{M_E} \right)^2 + \left( \frac{1}{M_P} \right)^2 + \left( \frac{1}{M_D} \right)^2 + \dots \right]^{-\frac{1}{2}}$$

## Non-resonant Conditions

223 The procedure outlined in the previous Sections is intended to provide means for predicting magnitudes of vibration at resonant criticals in the operating speed range.

In many cases, however, levels of vibration, sufficiently high to warrant further consideration, may occur under non-resonant conditions away from critical speeds.

This situation frequently arises near the maximum continuous engine speed where the machinery may be operating on the flank of a particularly powerful critical, or where the cumulative effect of a complex of resonant criticals and flank conditions, attributable to several orders of harmonic excitation, may have to be taken into account.

224 The normal procedure for estimating the magnitude of vibration on the flank of a single critical is to calculate first the amplitude,  $\theta_0$  at resonance (as in 214). The amplitude  $\theta_F$  for the flank condition (corresponding to  $\theta_1$ ), is then obtained from the following formula:—

$$\theta_F = \pm \theta_0 \left[ \left\{ 1 - \left( \frac{N}{N_C} \right)^2 \right\}^2 + \left( \frac{N}{N_C} \right)^2 \frac{1}{M^2} \right]^{-\frac{1}{2}}$$

where

$N$  = engine speed at the required flank condition,

$N_C$  = critical speed,

$M$  = dynamic magnifier at resonance.

The required magnitudes of flank amplitude, torque and stress in the system are deduced from the application of  $\theta_F$  as a scaling factor to the tabulated natural frequency data (Table R (E) 2.2), on the assumption that the latter remain valid for the flank conditions as well as for resonance, which is normally sufficiently accurate. If the harmonic torque component at the engine speed considered differs appreciably from that at the critical speed, the former value is used as the basis for calculating  $\theta_0$ .

225 The foregoing approach, in which a particular non-resonant operating condition is considered to be situated on the flank of an adjacent isolated critical may, in certain cases, be an over-simplification. This situation arises in systems having a number of natural frequencies fairly close to one another, such that a single harmonic order appreciably excites several modes of vibration, whose contributions to the total vibratory conditions cannot be ignored. In these circumstances the vibratory conditions are to be investigated by non-resonant forced frequency tabulation techniques, and where damping has an important influence, this is to be included in the calculation procedure.



**TABLE R (E) 2.1(a)**  
**PARTICULARS OF OIL ENGINE MACHINERY**

Ship's Name:—	
Description and Class:—	Yard No.
Shipbuilders:—	Engine No.
Enginebuilders:—	
Description of Machinery:—	

**Engine Data:—**

Type:—	Max. Press.:—
Cycle:—	M.I.P.:—
No. of Cylinders:—	Max. cont. engine power:—
Bore:—	Max. cont. engine rev/min:—
Stroke:—	Idling rev/min:—
"Vee"-angle:—	Balance Wts. disposition:—
Firing Order:—	inertia:—
	Span of Bearings:—
	Crankshaft Plan No.:—

**Propeller and Shafting Data:—**

Propeller Dia.:—	No. of Screwshafts:—
No. of Blades:—	Max. cont. rev/min:—
Fixed Pitch/C.P.:—	Working Range of rev/min:—
Inertia (dry):—	Cont. Liner/Oil Gland:—
Propeller Plan No.:—	Shafting Layout Plan No.:—

**Auxiliary Machinery Data:—**

Generator Make and Type:—	Rotor Shaft Plan No.:—
Rating AC/DC, KVA/KW, full load/no load rev/min:—	
Whether Unit on Resilient Mountings:—	

**Gearing Data:—**

Make and Type:—	Gearing Plan No.:—
Speed Ratios:—	

**Vibration Damper Data:—**

Make and Type:—
Seismic Mass Inertia:—
Hub or Casing Inertia:—
Spring Stiffness, Static/Dynamic:—
Damping Coefficient:—

**Flexible Coupling Data:—**

Make and Type:—
Stiffness, Static/Dynamic:—
Max. Cont. Vibratory Torque:—
Coupling Damping:—

**Additional Features**

TABLE R (E) 2.1(b)

Equivalent Dynamic System:—

MASS NUMBER	DESCRIPTION	INERTIA J kg m <sup>2</sup> (kg cm sec <sup>2</sup> )	SHAFT STIFFNESS C MN m/rad (10 <sup>6</sup> kgf cm/rad) or I/C	MINIMUM SHAFT DIAMETER d mm (cm)	SHAFT SPEED RE- DUCTION G	ENGINE CYLINDER FIRING ANGLES, degrees	
						A	B

## NOTES TO TABLE R (E) 2.1(b)

The minimum sectional modulus of the shaft in torsion, Z, in mm<sup>3</sup> (cm<sup>3</sup>), is to be stated where the shaft is not of solid circular cross-section.

The speed reduction, G, in a geared system is related to the crankshaft speed, i.e.  $G = \text{crankshaft speed} / \text{shaft speed}$ .

The cylinder firing angles are to indicate the true angular position for each cylinder in the firing sequence whether 2- or 4-stroke cycle. For "Vee" engines the firing angles for both cylinders on one pin are required at each crank.

Columns A and B relate to the cylinder banks of a "Vee" engine. In the case of an "in-line" engine only one column is required.



TABLE R (E) 2.2

Frequency,  $F =$                       hertz (cycles/min)                      No. of Nodes =                       $\omega^2 =$

Col. 1.	Col. 2.	Col. 3.	Col. 4.	Col. 5.	Col. 6.
Mass Number	Relative Amplitude $\Delta$ (Radians)	Inertia Torque $J \omega^2 \Delta / 10^6$ MN m ( $10^6$ kgf cm)	Modal Shaft Torque $\Sigma J \omega^2 \Delta / 10^6$ MN m ( $10^6$ kgf cm)	$J \Delta^2$ kg m <sup>2</sup> (kg cm sec <sup>2</sup> )	Nominal Shaft Stress Factor $\frac{G}{Z} \Sigma \frac{J \omega^2 \Delta}{10^6}$ kN/mm <sup>2</sup> ( $10^6$ kgf/cm <sup>2</sup> ) *
$\Sigma (J \Delta^2) =$					

$\omega$  = natural phase velocity of the mode of vibration (rad/sec),

$F$  = natural frequency of vibration

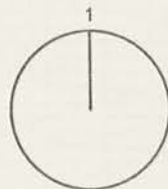
$$\text{i.e. } F = \frac{\omega}{2\pi} \text{ hertz} \quad \left( F = \frac{60 \omega}{2\pi} \text{ cycles/min} \right)$$

(For definition of other symbols see Table R (E) 2.1(b))

\* Per radian at No. 1 cylinder

TABLE R (E) 2.3

CRANK ARRANGEMENT



VECTOR SUMMATION

Orders	Resultant for 1 radian at No. 1 cylinder		
	1-node	2-node	3-node



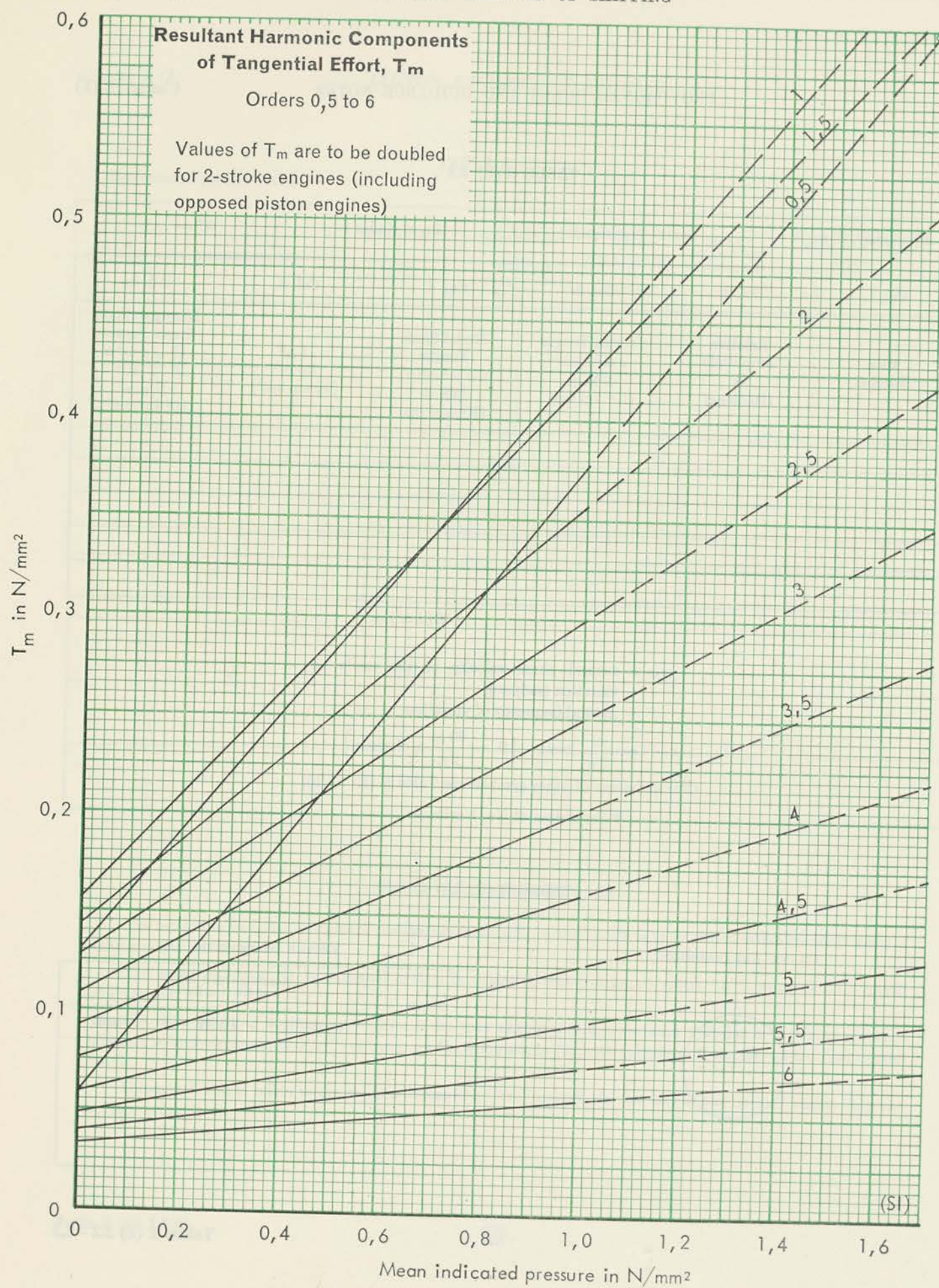


Fig. R (E) 2.1(a)

FIG. R (E) 2.1(a) (SI)



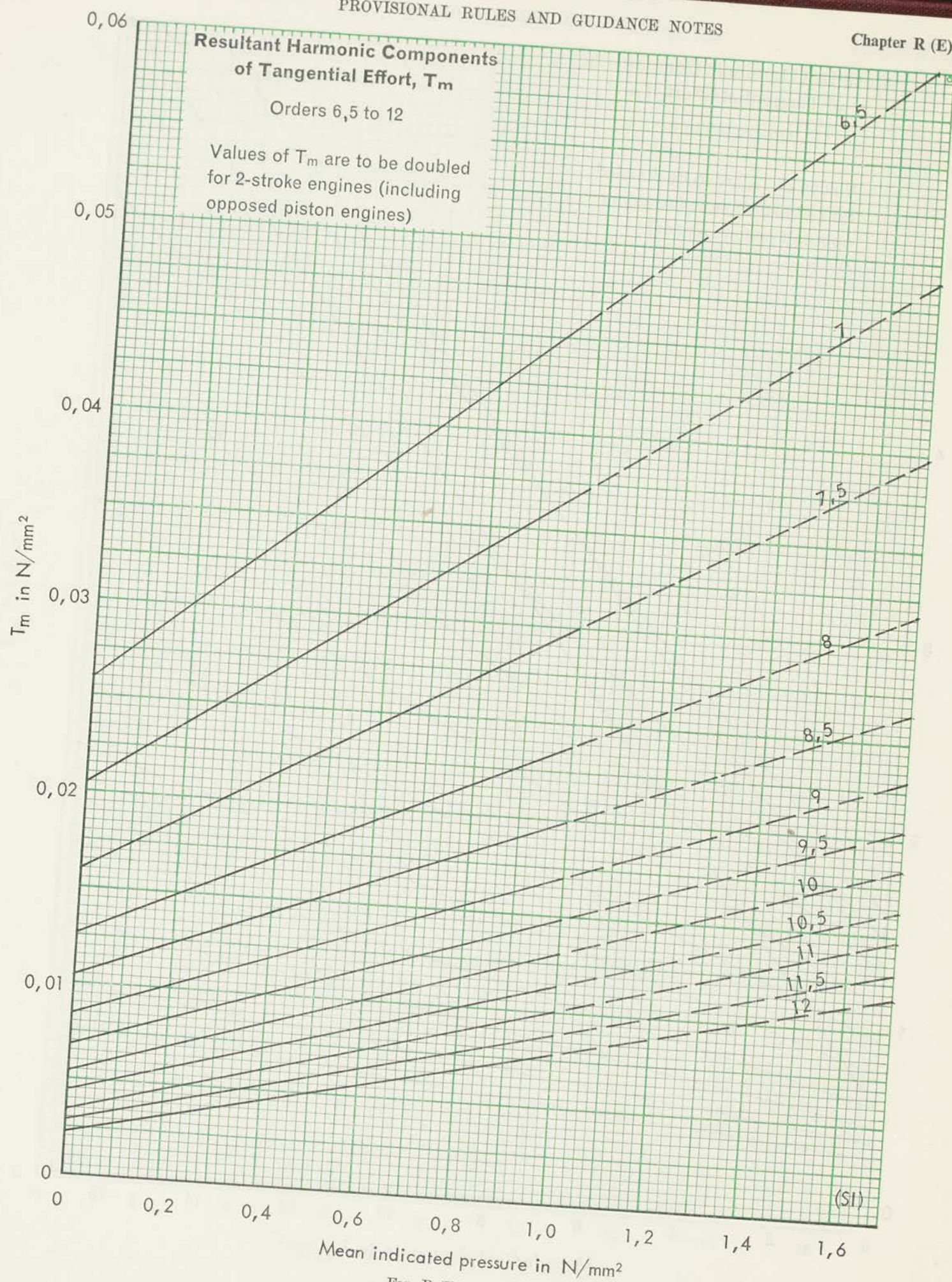


FIG. R (E) 2.1(b) (SI)



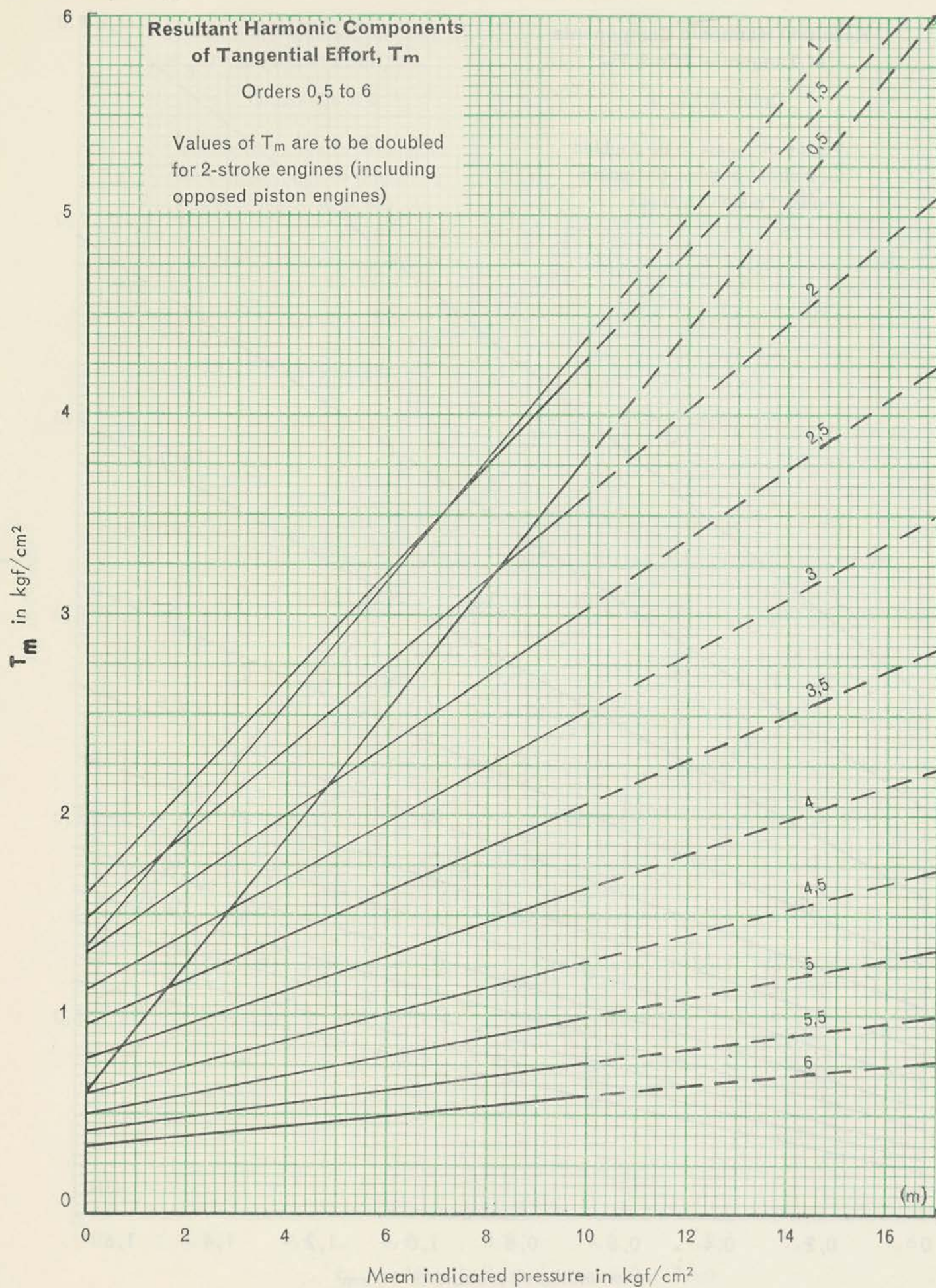


FIG. R (E) 2.1(a) (metric)

Fig. R (E) 2.1(a)



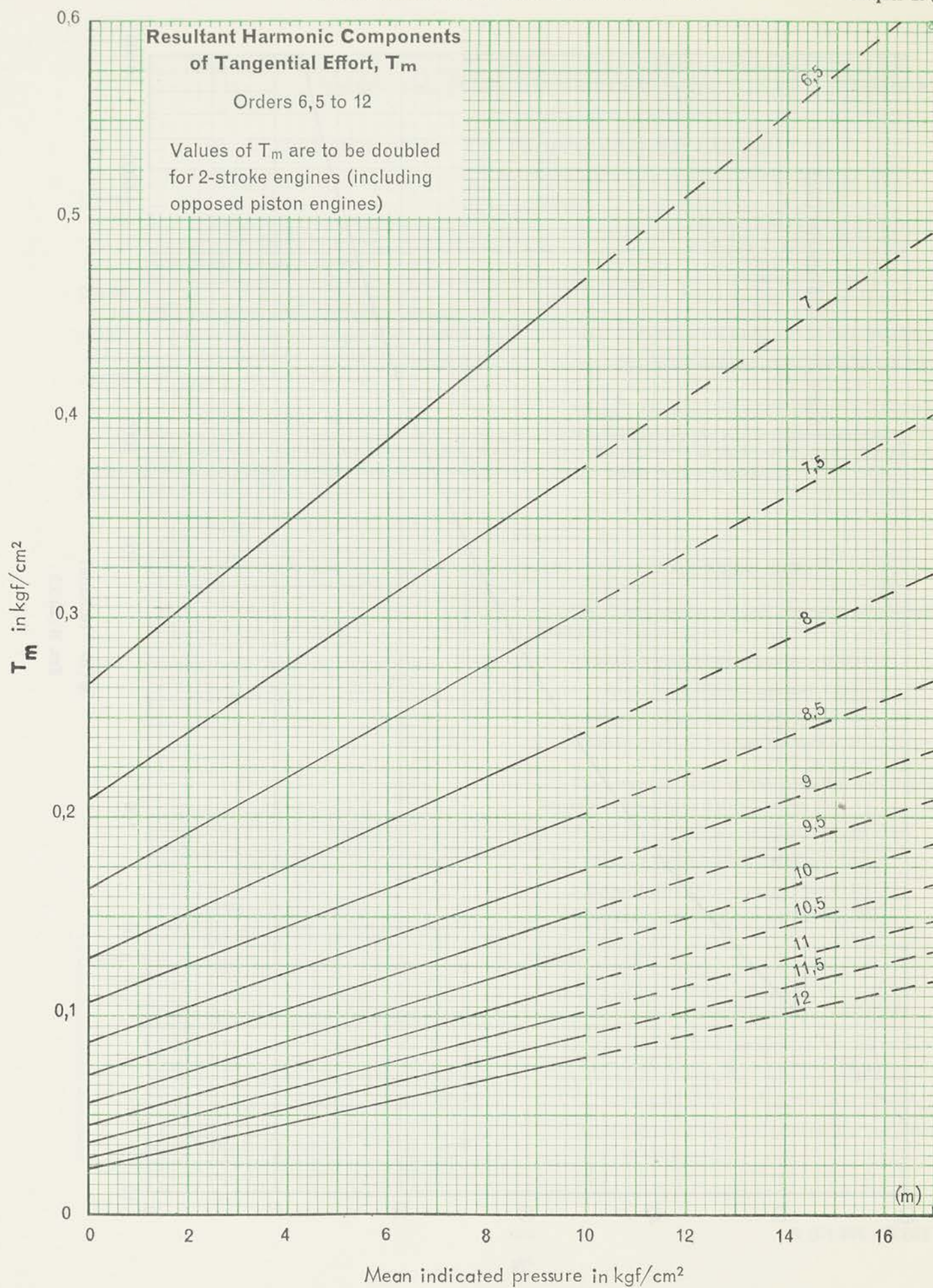


FIG. R (E) 2.1(b) (metric)





FIG. R (E) 2.2



## R (G) GUIDANCE NOTES ON PROPELLER-HULL CLEARANCES

## Symbols

- 101  $D$  = propeller diameter, in metres,  
 $R$  = propeller radius, in metres,  
 $L$  = length of ship, in metres.

## General

102 The following recommendations indicate the minimum clearances between the propeller and sternframe, rudder or hull that should be provided to minimize the possibility of propeller excited vibration.

## SINGLE SCREW SHIPS

103 The clearances between the propeller and the rudder or sternframe should not be less than given in Table R (G) 1.1, see also Fig. R (G) 1.1.

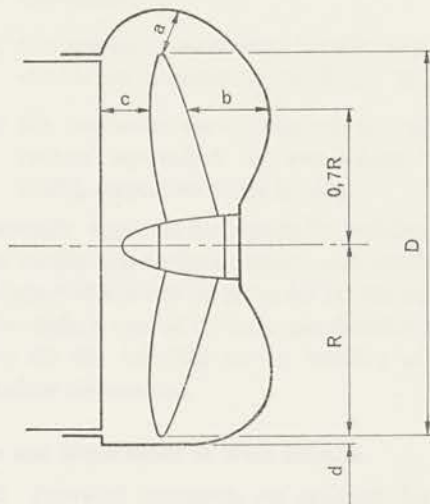


FIG. R (G) 1.1

TABLE R (G) 1.1

NUMBER OF BLADES	a*	b*	c*	d
3	$1,2k_1D$	$1,8k_1D$	$0,12D$	$0,03D$
4	$1,0k_1D$	$1,5k_1D$	$0,12D$	$0,03D$
5	$0,85k_1D$	$1,275k_1D$	$0,12D$	$0,03D$
6	$0,75k_1D$	$1,125k_1D$	$0,12D$	$0,03D$

where

$$k_1 = \left(0,1 + \frac{L}{3050}\right) \left(\frac{3,48 C_b H}{L^2} + 0,3\right)$$

$$\left(k_1 = \left(0,1 + \frac{L}{3050}\right) \left(\frac{2,56 C_b H}{L^2} + 0,3\right)\right)$$

$C_b$  = moulded block coefficient at load draught,

$H$  = maximum designed shaft power in kW (shp).

\*NOTE. In no case should "a" be less than  $0,10D$ , "b" less than  $0,15D$ , or "c" less than the maximum thickness of the rudder. The thickness is to be measured at the  $0,7R$  line above the shaft centreline.

## TWIN SCREW SHIPS

104 The propeller tip-hull clearance should not be less than:—

3 blades:  $1,2k_2D$  but not less than  $0,2D$

4 blades:  $1,0k_2D$  but not less than  $0,2D$

5 blades:  $0,85k_2D$  but not less than  $0,16D$

6 blades:  $0,75k_2D$  but not less than  $0,16D$

The clearance between the propeller and the shaft brackets or bossing should not be less than:—

3 blades:  $1,2k_2D$  but not less than  $0,15D$

4 blades:  $1,0k_2D$  but not less than  $0,15D$

5 blades:  $0,85k_2D$  but not less than  $0,15D$

6 blades:  $0,75k_2D$  but not less than  $0,15D$

where

$$k_2 = \left(0,1 + \frac{L}{3050}\right) \left(\frac{1,74 C_b H}{L^2} + 0,3\right)$$

$$\left(k_2 = \left(0,1 + \frac{L}{3050}\right) \left(\frac{1,28 C_b H}{L^2} + 0,3\right)\right)$$

$C_b$  = moulded block coefficient at load draught,

$H$  = maximum total designed shaft power installed, in kW (shp)





## R (H) PROVISIONAL RULES FOR REPAIRS BY WELDING

## PART 1

## NEW STEEL CASTINGS FOR CRANKSHAFTS

Section 1**General**

101 Welded repairs are only to be undertaken when:—

- (a) the repairs are considered to be necessary and are approved by the Surveyor. Consideration must be given first to the blending of grooves formed by the removal of shallow defects, or to the machining of a surface where there is excess metal on the Rule dimension.
- (b) the specified maximum tensile strength of the steel is not in excess of 640 N/mm<sup>2</sup> (65 kgf/mm<sup>2</sup>).
- (c) the maximum carbon content and the maximum carbon equivalent do not exceed 0,30% and 0,65% respectively (see Q 513).

Generally, approval for repairs by welding will only be given to rectify areas where random and accidental defects arise. Approval will not be given for (1) the rectification of repetitive defects caused by improper foundry technique or practice; (2) the building up by welding of surfaces or large shallow depressions.

**Position and Dimensions of Weld Repairs**

102 Provided Surveyors are satisfied that repairs by welding are justified, they may authorize repairs to the surfaces of webs, within the following limits:—

- (a) In general, the volume of the largest groove which is to be welded is not to exceed  $3,2 t \text{ cm}^3$  where  $t$  is the web axial thickness, in cm. The total volume of all grooves which are to be welded is not to exceed  $9,6 t \text{ cm}^3$  per web.
- (b) The welds do not extend within the cross-hatched zones marked on Figs. R (H) 1.1 and R (H) 1.2 for fully-built and semi-built throws, respectively.
- (c) Larger repairs on balance weights may be permitted at the discretion of the Surveyor, provided such repairs are wholly contained within the balance weight and do not affect the strength of the web.

103 Weld repairs may also be authorized in the surface of the bore for the journal (or pin) within the following limits:—

- (a) In general, the welds are to be not less than 125 mm apart.
- (b) The welds are not located within circumferential bands of  $\frac{t}{5}$  from the edges of the bores, nor at any position within the inner 120° arc of the bores, as cross-hatched on Figs. R (H) 1.1 and R (H) 1.2.
- (c) The volume of the largest weld is not more than about  $1,1 t \text{ cm}^3$  where  $t$  is the web axial thickness at the bore, in cm, and not more than three welds are to be made in any one bore surface.

104 At the discretion of the Surveyor, the size of a groove may be increased somewhat beyond the limiting sizes given in 102 (a) or 103 (c) if the removal of further metal will facilitate welding.

**Repair Procedure**

105 All castings are to be given a preliminary refining heat treatment prior to the commencement of weld repairs.

Only experienced welders are to make the repairs and, at any time, the Surveyors may require a welder to demonstrate his ability to make a sound weld.

106 After all defective material has been removed from a region, and this has been proved in the presence of the Surveyor by magnetic particle inspection or other suitable method, the depression may be suitably shaped to allow good access for welding.

107 Before welding, the material is to be preheated to a temperature of not less than 200°C. Where possible preheating should be carried out in a furnace. The preheat temperature is to be maintained until welding is completed and preferably until the casting is charged to the furnace for post-weld heat treatment.

108 Welds are to be made by the electric arc process in the downhand (flat) position using low hydrogen electrodes which will produce a deposited metal in no way inferior in properties to the parent metal.

109 On completion of the repairs the casting is to be given a suitable heat treatment, which is to consist of either full annealing or normalizing and tempering. Where small isolated defects are revealed after completion of full heat treatment as above, welding repairs followed by a stress relieving treatment within the range 630 to 660°C may be permitted.

110 Welds are to be dressed smooth by grinding and

proved by magnetic particle inspection. The surfaces of the welds and adjacent parent steel are to be free from harmful defect.

#### Documentation

111 The foundry is to provide Surveyors with a statement and/or sketch detailing the extent and location of the welded repairs made to each casting together with details of the heat treatment carried out at all stages.

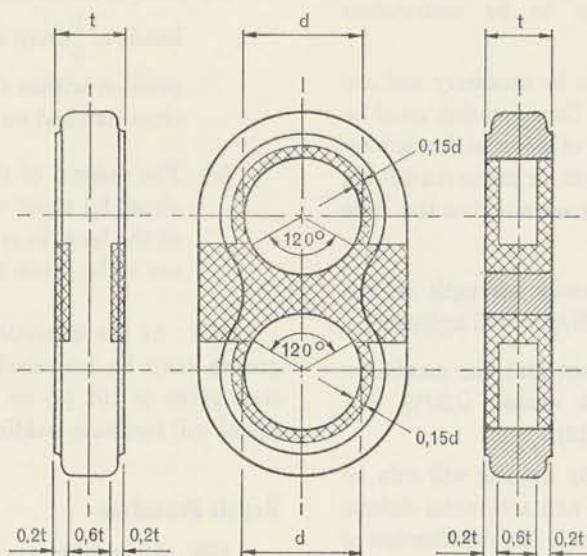


FIG. R (H) 1.1

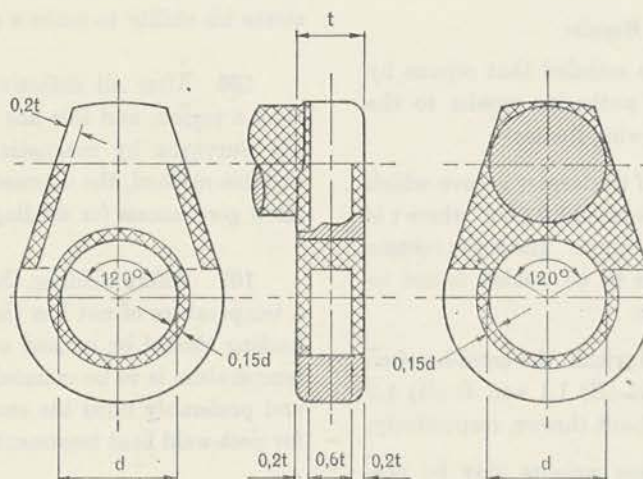


FIG. R (H) 1.2



## PART 2

NEW COPPER ALLOY PROPELLERS AND  
PROPELLER BLADE CASTINGS

## Section 2

## General

**201** Repairs by welding may be made to depressions formed by the removal of casting defects in new propellers and propeller blades manufactured in accordance with the requirements of Q 9, provided that the repairs are carried out in accordance with the following requirements.

**202** All repairs to propellers are to be carried out in accordance with approved procedures and practices, and are to be completed to the Surveyors' satisfaction. Welding repairs are to be carried out under cover and preferably in a workshop. The welding apparatus is to be so arranged that the welding work is carried out in positions free from draughts and adverse weather conditions.

**203** Before deciding to repair by welding, consideration should be given to blending of depressions produced by the removal of superficial defects. Welds having an area less than 5 cm<sup>2</sup> should, in general, be avoided.

Where local pores are present in the surface of the end face or bore of a propeller boss which do not themselves adversely affect the strength of the casting, they may be filled with a suitable plastic filler after the appropriate preparation of the defective area.

## Position and Dimensions of Weld Repairs

**204** Individual repairs should, in general, be limited to depressions having areas not greater than those given in 205 and 206. Where it is proposed to exceed the areas permitted by 205 and 206, the nature and extent of the work is to be approved by the Surveyors before commencement of repairs.

The length of an individual repair in any direction measured in centimetres, is not to be greater than:—

$$2 \times \sqrt{\text{Permitted area of that repair in cm}^2}$$

Where it is proposed to exceed the permissible length of an individual repair, the extent of the work is to be approved by the Surveyors before commencement of the repairs.

**205** Each blade of a propeller shall be divided into three zones A, B and C as shown in Fig. R (H) 2.1, and the

extent of repairs in each zone on each side of the blade is to be as follows:—

- (a) In zone A no weld repairs are permitted.
- (b) In zones B and C, the maximum permitted area of one individual repair shall be 0.6 per cent of the area of one blade, and the total repaired area in the two zones shall not exceed 2 per cent of the area of one blade. Of this total, not more than two-fifths shall be in zone B.

On small propellers, individual repairs not exceeding 60 cm<sup>2</sup> will be allowed in each of zones B and C. The total area of repairs in each of these zones should not exceed 100 cm<sup>2</sup>.

NOTE. The area of one blade is defined as  $0.79 \frac{D^2 B}{N}$ ,

where D = finished diameter of propeller,

B = developed area ratio,

N = number of blades.

**206** The remainder of the propeller shall be divided into regions as follows:—

- (a) the bore,
- (b) the outer face of the boss to the mid-radius of the blade fillet,
- (c) each end face of the boss,
- (d) the journals of separately cast blades,
- (e) the flange of a loose blade up to the mid-radius of the fillet.

In each of these regions, the maximum area of one repair shall be 1.5 per cent of the area of the region, and the total area of repairs shall not be greater than 5 per cent of the area of the region. On small propellers, individual repairs not exceeding 17 cm<sup>2</sup> will be allowed in each of these regions. The total area of repairs in each of these regions should not exceed 50 cm<sup>2</sup>.

**207** Where separate blades have journals cast integral at the root, weld repairs are not generally permitted in the fillet radii or within 12 mm of the ends of these radii. Where repairs are proposed in these regions, full particulars are to be submitted for special consideration. The permitted areas of repairs on the journal are as stated in 206.

**208** At the discretion of the Surveyor, an increase in the area of a depression beyond the limits stated in 204, 205 and 206 may be permitted if removal of further metal will facilitate welding.



**Repair Procedures**

**209** Under no circumstances should weld metal be deposited on defective or porous material. Defects may be removed by chipping and/or grinding. Complete removal of a defect is to be demonstrated by grinding smooth the surface of the depression followed by visual examination and dye penetrant testing.

**210** Welds should preferably be made in the downhand (flat) position with approved electrodes and filler wire. Where necessary, suitable preheat is to be applied before welding and the preheat temperature is to be maintained until welding is completed.

**211** All repairs by welding are to be made by welders who have qualified by completing satisfactory weld tests in accordance with procedures proposed by the foundry and approved by the Surveyors. Each foundry is to keep records of qualification tests of welders and the repairs they have effected. If a welder has not undertaken repair work for 12 months, or the Surveyors have other reasons to doubt his

ability, he must re-qualify before making further welded repairs.

**Heat Treatment**

**212** With the exception given in 215, all welded repairs, no matter how small, in areas of solid propellers exposed to sea water and all repairs to separately cast blades are to be stress relief heat treated. Where other repairs to a propeller necessitate furnace stress relief heat treatment, any welded repairs to the end faces or bore of the boss are to be completed before the heat treatment operation.

**213** Where possible, stress relief heat treatment is to be carried out in a furnace having suitable atmosphere and temperature control. Sufficient thermocouples are to be attached to the propeller to measure the temperature at positions of extremes of thickness.

**214** Stress relief soaking time depends on the temperature within the permissible range as shown in Table R (H) 2.1. Cooling from the soaking temperature should be suitably controlled to minimize residual stresses.

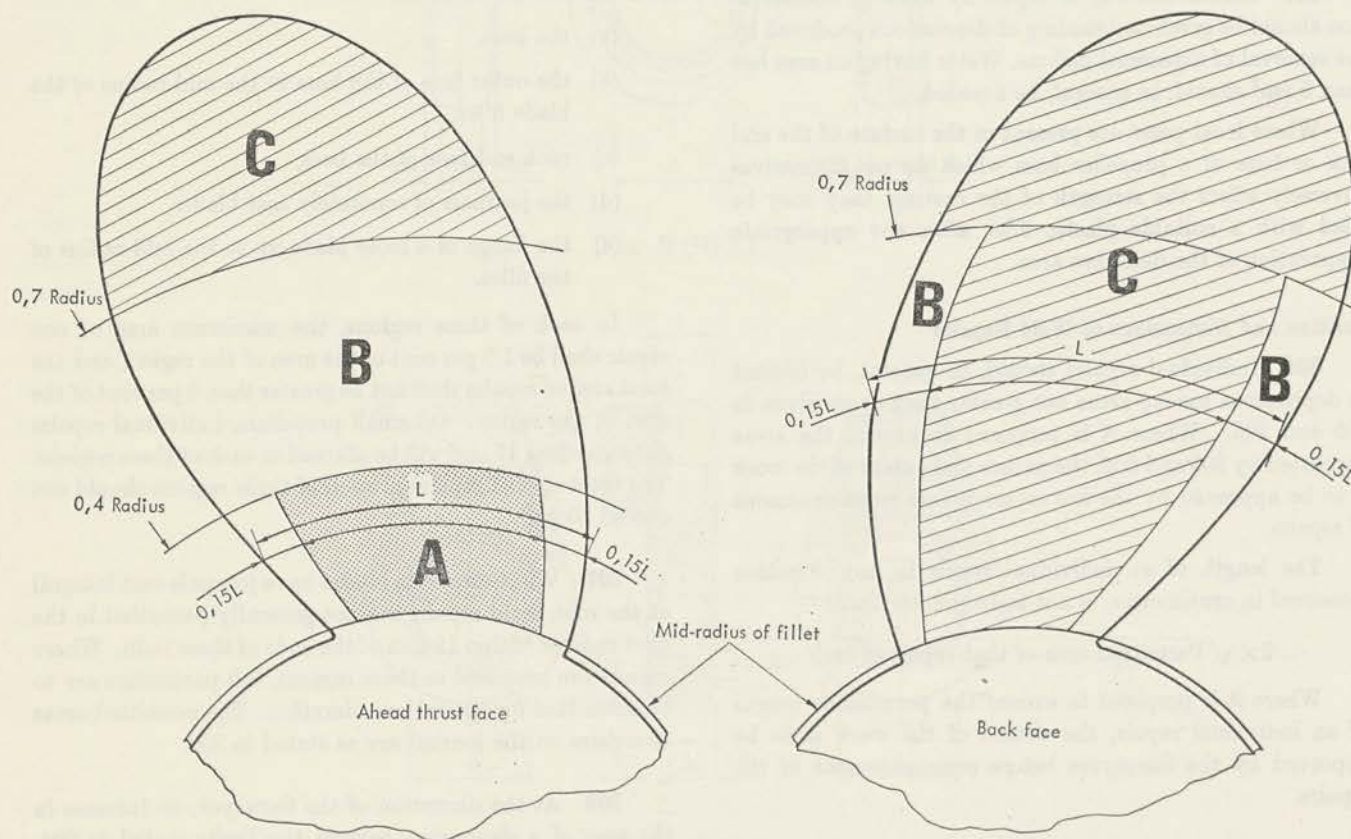


FIG. R (H) 2.1



TABLE R (H) 2.1

**SOAKING TIMES FOR STRESS RELIEF HEAT TREATMENT  
OF BRONZE PROPELLERS**

STRESS RELIEF TEMPERATURE  °C	SOAKING TIMES (hours)			
	MANGANESE BRONZES		ALUMINIUM BRONZES	
	Hours per 25 mm of thickness	Maximum recommended total time	Hours per 25 mm of thickness	Maximum recommended total time
350	5	15	—	—
400	1	5	—	—
450	$\frac{1}{2}$	2	5	15
500	$\frac{1}{4}$	1	1	5
550	$\frac{1}{4}$	$\frac{1}{2}$	$\frac{1}{2}$	2
600	—	—	$\frac{1}{4}$	1
650	—	—	$\frac{1}{4}$	$\frac{1}{2}$

**215** Repairs to defects in propellers made in aluminium bronze having less than 6 per cent manganese may be accepted without stress relief heat treatment, provided that no welding is carried out to the edge of the blade within 0.7 radius or to the critical regions of the flange of a loose blade.

**216** Manganese bronze propellers and propeller blades are to be stress relief heat treated within the temperature range of 350 to 550°C. The range of stress relief heat treatment of aluminium bronze propellers depends on the manganese content of the alloy. Where this is less than 6 per cent, the range is to be 500 to 650°C. Where the manganese content exceeds 6 per cent, the range is to be 450 to 650°C.

**217** Alternatively, local stress relief heat treatment may be accepted, provided the Surveyor is satisfied that the technique will be effective and that adequate precautions are taken to prevent the introduction of detrimental temperature gradients. Where local stress relief heat treatment is approved, adequate temperature control is to be provided. The area of the propeller or blade adjacent to the repair is to be suitably monitored and insulated to ensure that the required temperature is maintained and that temperature gradients are moderate.

**218** Where it is proposed to adopt alternative means of stress relief, full particulars are to be submitted for special consideration.

#### Inspection

**219** On completion, welds are to be ground smooth for visual examination and dye penetrant testing. Where a propeller, or propeller blade, is to be stress relief heat treated, a visual examination should be made before heat treatment, and both visual and dye penetrant examinations are to be made after the stress relief heat treatment.

#### Records

**220** The foundry is to maintain full records detailing the weld procedure, heat treatment, and extent and location of repairs made to each propeller. These records are to be available for review by the Society's Surveyors, and copies of individual records are to be furnished to the Surveyors on request.

**221** The Society reserves the right to restrict the amount of repair work accepted from a manufacturer when it appears that repetitive defects are the result of improper foundry techniques or practices.





## R (J) PROVISIONAL RULES FOR THE CLASSIFICATION OF TANKERS INTENDED FOR THE CARRIAGE OF LIQUID CHEMICALS IN BULK

### General

The following Rules apply to ships having tanks integral with the hull, constructed generally in accordance with the provisions of the Society's Rules and Regulations for oil tankers, but which are intended specifically to carry liquid cargoes having hazards greater than or different from those associated with normal petroleum cargoes. The Rule arrangements do not, however, in general preclude the carriage of petroleum cargoes or of liquids having similar hazards.

Except in cases where the ship is intended to carry a specific chemical, the arrangements of tanks and pumping and piping systems are to be such as will permit the handling and simultaneous safe carriage of different liquid cargoes.

Subdivision and damage stability, also safety equipment for the ship and crew, are not covered by these Rules, and for these and any other special requirements of National or Port Administrations, reference should be made to the appropriate authority.

These Rules do not cover the segregation or compatibility requirements of chemical cargoes normally associated with ship operation. For other segregation requirements, *see* relevant paragraphs of these Rules.

The Rules are subdivided as follows:—

- Part 1. Classification.
- Part 2. Hull Construction.
- Part 3. Pumping and Piping arrangements.
- Part 4. Tables of Cargoes.
- For Electrical Requirements, *see* M 16.

### PART 1 CLASSIFICATION

#### Section 1

##### General

101 The class notations which may be assigned by these Rules are related to ships having special features which make them suitable for the carriage of liquid cargoes which have been provisionally grouped in Tables R (J) 1, R (J) 2 and R (J) 3 (*see* Part 4) according to the degree and nature of the hazard involved. Cargoes may be added to these lists or may be transferred from one list to another as further experience may require.

##### Class Notations

102 Ships complying with the requirements of these Rules, including any special requirements for cargoes in Table R (J) 1, will be assigned the class 100A1 chemical tanker—Type A and may also carry the cargoes listed in Tables R (J) 2 and R (J) 3.

103 Ships complying with the requirements of these Rules, including any special requirements for cargoes in Table R (J) 2, will be assigned the class 100A1 chemical tanker—Type B and may also carry the cargoes listed in Table R (J) 3.

104 Ships complying with the Rules for oil tankers, and the general cargo segregation and pump room ventilation requirements of these Rules, will be assigned the class 100A1 chemical tanker—Type C and may carry the cargoes listed in Table R (J) 3.

105 Where a ship is designed to carry only a specific cargo, the name of the cargo will be included in the class notation, e.g. 100A1 sulphuric acid tanker, and the requirements will be modified as considered necessary for the particular hazards involved.

106 A list of cargoes for the carriage of which the ship has been approved will be attached to the Classification Certificate and this will be suitably modified where the additional requirements mentioned in the Tables have not been complied with.

Where cargoes are to be carried which are not on the approved list, it will be the Owners' responsibility to ensure that full particulars of such cargoes are forwarded to the Society for approval.

107 Additional notations may be given for the following features:—

- (a) Number of different cargo segregations, e.g. "cs 4".
- (b) Suitability of scantlings for high relative density (specific gravity) cargoes, e.g. "SG 2.0".
- (c) Provision of inert gas system for cargo tanks, "IGS".
- (d) Tanks constructed of special corrosion resistant materials, e.g. stainless steel ("CR(s.stl)"), or lined with special corrosion resistant linings, e.g. rubber lining, ("CR (r.l)").

108 Where all cargo tanks on a ship are not adapted to comply with the requirements for one of the class nota-



tions given above, the notation will be suitably amended in the *Register Book*, e.g. 100A1 chemical tanker—Type A 1-5 centre tanks; Type B 1-5 wing tanks.

### Characteristics of Cargoes

**109** Cargoes listed in Table R (J) 1 are those which require segregation from the sea by cofferdams, double bottoms, void spaces, etc., on grounds of their reactivity with water, their toxicity or the need for special materials of construction. In addition, such cargoes may have hazards which require special precautions to control the release of dangerous vapours and accidental release of dangerous liquids.

**110** Cargoes listed in Table R (J) 2 are those which do not require segregation from the sea, but need significant increases in precautions to control the release of dangerous vapours and liquids as compared with normal petroleum cargoes.

**111** In addition to the characteristics given in 109 and 110, the cargoes listed in Tables R (J) 1 and R (J) 2 may have a flash point (closed cup test) below 60°C but may, in addition, have fire hazards in excess of those associated with normal petroleum cargoes, by virtue of wide flammable range or high vapour pressure, or auto-ignition temperature below 180°C, or a combination of these.

**112** Cargoes listed in Table R (J) 3 are those which have hazards similar to and no greater than normal petroleum cargoes having a flash point (closed cup test) below 60°C.

### Special Cargoes not listed in the Tables

**113** Where it is proposed to carry a cargo the temperature of which requires to be maintained at or below ambient temperature for reasons of safe carriage, the temperature control equipment will be specially considered in relation to the physical and chemical characteristics of the cargo. The temperature control equipment in these cases is to be built under survey and a suitable additional notation assigned.

In general, ships constructed in accordance with the Rules are not intended to carry cargoes having a temperature below 0°C.

**114** There are individual special requirements for the following cargoes:—

Acrolein, Carbon Disulphide, Ethyleneimine, Ethyl Ether, Hydrochloric Acid, Hydrofluoric Acid, Propylene Oxide, Sulphur (molten), Phosphorous (molten), Tetraethyl Lead.

## PART 2

### HULL CONSTRUCTION

#### Section 2

#### PLANS

**201** The following plans and information are additional to those required to be submitted by D 110 and D 4012:—

1. Ship General Arrangement giving location of:—
  - (a) hatches, tank cleaning and other openings to the cargo tanks.
  - (b) doors, hatches and other openings to enclosed spaces used for cargo handling.
  - (c) doors, hatches and other openings (e.g. vents) to accommodation and stores which give access to the cargo tank area.
  - (d) coated tanks or tanks constructed of special materials.
  - (e) proposed grouping of cargo tanks for cargo segregation purposes (coloured if necessary for ease in identification).
2. Diagrammatic arrangements and capacity of ventilation arrangements to spaces to which access is necessary for cargo handling.
3. Plans of fire protection, detection and extinction for the cargo tanks.

#### Section 3

### SHIP ARRANGEMENT

#### General

**301** All accommodation is to be arranged clear of the cargo tanks and adjacent cofferdams and cargo pump rooms in ships classed 100A1 chemical tanker—Type A or 100A1 chemical tanker—Type B.

**302** Access openings are not to be arranged in forward bulkheads of accommodation. Access openings are also not to be arranged in sides of accommodation (wheelhouses excepted) within a distance from the aft end of the adjacent cargo tank of  $\frac{L}{25}$  metres where  $L$  is the length of the ship, subject to a minimum of 4.5 m for the first two tiers above the tank deck and a minimum of 3 m for the third tier and above. Windows or port lights to the accommodation in these areas are to be of the fixed type except for emergency escape windows, if fitted.



303 If a deckhouse is fitted in lieu of a poop, the front of the house should be extended in the form of a sill to the ship's side for a height of at least 600 mm above the tank deck.

304 Two separate means of access from the open deck are generally to be provided to cofferdams, wing tanks and double bottom tanks adjacent to cargo tanks. Alternatively, the access to double bottom tanks may be via pump rooms, deep cofferdams or similar compartments but would be subject to special consideration. Within such spaces a minimum of 380 mm clear access is to be obtained between stiffening members, and a minimum of 760 mm between bulkhead plating.

305 Pipe tunnels, and duct keels to which access is normally required for operational purposes, are to be provided with means of access spaced not more than 60 m apart. In all cases, however, access is to be provided at each end of the tunnel or duct keel. Access openings to the foregoing spaces are to be from positions inside a pump room or deep cofferdam or from a trunk led to the open deck.

306 Arrangements should be made to provide easy access to below-deck cargo pump rooms. In general, ladders should not be arranged vertically, and intermediate platforms should be fitted at vertical intervals of about 6 m. Ladders and platforms should have guard rails and permanent provision should be made for attaching a hoist for use in emergencies.

307 A continuous saveall is to be arranged on the weather deck, port and starboard, throughout the cargo tank area to contain minor spillage.

308 For ships classed 100A1 chemical tanker—Type C in which it is desired to fit midship accommodation, such accommodation is to be arranged one tier clear of the tank deck and there is to be no access or any other opening in the tank deck in way of such accommodation, nor any direct communication between the accommodation and the space immediately above the tank deck. The space immediately above the tank deck under midship accommodation is not to be used as a workshop or as a storage space for combustible materials. If fresh water tanks are located in this space they are to be separated from the tank deck by a cofferdam, which may be open.

#### Cargo Segregation—General

309 Cargoes which could react hazardously with one another should be separated by a cofferdam, pump room, void space, empty tank or tank containing a mutually

compatible cargo, and in addition there is to be corresponding segregation of the pumping and piping systems. The number of groups of tanks which comply with the foregoing will be recorded in the class (see R (J) 107(a)).

310 Proposals for grouping tanks which will permit cargo segregation should be clearly indicated on the plans.

311 For isolation of piping systems serving groups of tanks which may contain incompatible cargoes, see R (J) 1204.

312 Cofferdams are to be provided at the forward and after ends of the cargo spaces in accordance with D 4010, except that oil fuel bunker tanks will only be accepted in lieu of a cofferdam for ships classed 100A1 chemical tanker—Type C, i.e. for cargoes in Table R (J) 3.

#### Cargo Segregation Requirements applicable only to the class 100A1 Chemical Tanker—Type A

313 Tanks for the cargoes in Table R (J) 1 are to be fitted with a double bottom whose depth measured from top of keel to underside of double bottom tank top plating, is not to be less than the greater of the following:—

- (a)  $\frac{B_1}{15}$
- (b) 760 mm
- (c) As required by D 904

where  $B_1$  is the breadth of the ship measured at the load waterline, in metres.

However, the depth of double bottom need not exceed 6 m.

Sumps for drainage having a depth not greater than 200 mm may be fitted provided that their area is limited to that necessary for accommodation, inspection and servicing of the tank suction and does not form an excessive proportion of the inner bottom area of the tank served, and also provided that the double bottom structure in way of the sump is suitably reinforced. Attention is drawn to the fact that the regular carriage of full cargoes of high specific gravity may necessitate an increase in the height of double bottom.

314 Tanks for the cargoes in Table R (J) 1 are to be separated from the ship's side by at least 760 mm, but in the case of certain cargoes the minimum separation is to be  $\frac{B}{5}$  metres where  $B$  is the breadth of the ship measured at the load waterline. For those cargoes requiring increased



separation, reference should be made to column 8 of Table R (J) 1. The space or tank adjacent to the shell may be used for water ballast or cargoes in Tables R (J) 2 and R (J) 3, provided that the presence of different liquids in adjacent tanks does not constitute a reactivity hazard.

## Section 4

### MATERIALS OF CONSTRUCTION

**401** Unless otherwise stated in column 7 of Table R (J) 1, the material of construction is steel complying with Chapter P.

**402** Where stainless steel is an acceptable alternative to mild steel, it is generally to be of 18% Chromium, 12% Nickel, 2½% Molybdenum austenitic stainless type, with a maximum of 0,03% Carbon. Higher carbon contents may also be accepted provided the steel is of the carbide stabilized type. Items such as castings which do not embody welding and are bolted to the structure may, however, have a maximum carbon content of 0,08%.

**403** Where stainless steel tanks are arranged only to preserve product purity, the use of lower alloy stainless steels will be considered.

**404** To avoid accelerated corrosion, sea water ballast should not generally be carried in stainless steel cargo tanks. Mild steel fittings are not permitted in stainless steel cargo tanks.

A combined structure of mild steel and stainless steel may be used in water ballast spaces, e.g. wing cofferdams, when special protective measures are taken to reduce bimetallic corrosion such as coating the stainless steel with a suitable high duty paint to reduce attack on the mild steel.

**405** Proposals to protect the tank structure against corrosive attack from the cargo by the use of suitable linings will be specially considered.

**406** Certain materials or their alloys, principally copper, and to a lesser extent aluminium, magnesium and zinc, are unsuitable for use with certain cargoes as given in the Tables. Where such cargoes are to be carried, the use of these materials is not advised in locations where they may come into contact with the cargo or its vapours.

## Section 5

### STRUCTURAL DESIGN

**501** All-welded construction is to be employed in the cargo tank area and adjacent cofferdams, pump rooms and double bottoms.

**502** In general, D 40 applies to chemical tankers but, as this applies to ships carrying cargoes with a relative density not exceeding 1,025 and settings of pressure/vacuum valves in such ships are assumed to be set at positive/negative pressures not exceeding 0,014 N/mm<sup>2</sup> (0,14 kgf/cm<sup>2</sup>) and 0,004 N/mm<sup>2</sup> (0,04 kgf/cm<sup>2</sup>) respectively, increases in these values will generally entail modifications to the normal scantlings. In no case may tanks integral with the hull structure be used for a pressure valve setting exceeding 0,069 N/mm<sup>2</sup> (0,7 kgf/cm<sup>2</sup>).

**503** Where occasional cargoes are to be carried having a relative density greater than 1,025, tanks may be partially filled as an alternative to increasing the scantlings, provided the strength of the tank end structure is adequate for the forces which may be generated by movement of the cargo.

**504** The minimum thickness, *t*, of mild steel structure within the range of the cargo tanks for ships under *L* = 90 m is to be derived from the following formula, but is not to be less than 7 mm:—

$$t = 5,6 + 0,38L \text{ mm}$$

where *L* = length of ship, in metres.

**505** The section modulus of inner bottom longitudinals in ships fitted with double bottoms under the cargo tanks is not to be less than:—

$$\frac{I}{y} = \frac{s S^2}{120} (h + 0,9) \text{ cm}^3$$

*S* = span, in metres, measured between effective supports.

*h* = vertical distance, in metres, to the highest point of the tank excluding the hatchway but including expansion trunks if fitted,

*s* = spacing in mm.

Where relative density, *ρ*, of the liquid being carried exceeds 1,025, the modulus is to be multiplied by the factor

$$\frac{\rho}{1,025}. \text{ See also 503.}$$

### Heated Cargoes

**506** Where cargoes are to be heated and the sides and/or bottom of the heated tank are not in direct contact



with the sea, a thermal stress investigation may be necessary if the steel temperature of the cargo tanks exceeds 50°C. In such cases calculations giving estimated temperatures for the hull structure should be submitted, based on a sea temperature of 0°C and an air temperature of 5°C. Depending on the results of such investigations it may be necessary to limit the still water bending moment in such conditions.

A thermal stress investigation will generally not be necessary in ships carrying cargoes heated to temperatures approaching 80°C where the sides and/or bottom of the heated tank are in direct contact with the sea, provided the longitudinal bulkheads and ship sides are transversely framed.

507 Where heating ducts are integral with the tank structure, they are to be designed to withstand a head equal to the maximum pressure in the heating system, but in no case less than that imposed by the highest relative density cargo for which the tanks have been designed. *See also R (J) 1501 (d).*

### Cargo Tank Construction

#### PLATING

508 The thickness of plating forming the boundary bulkheads of cargo tanks, is not to be less than:—

$$t = 0,004 s \sqrt{\frac{\rho h}{1,025}} + K_c \text{ mm}$$

unless  $\frac{1000S_1}{s}$  is less than 4, when the thickness obtained from the above formula is to be multiplied by the factor  $1,1 - \frac{s}{2500S_1}$

where  $s$  = stiffener spacing, in mm, of welded stiffeners, or breadth, in mm, of flange or web, whichever is the greater, for corrugated bulkheads,

$\rho$  = relative density of the liquid to be carried and is not to be taken as less than 1,025. *See also 503.*

$h$  = vertical distance, in metres, from a point one-third of the height of the plate above its lower edge to the highest point of the tank excluding the hatchway but including expansion trunks if fitted, or half the distance to the top of the overflow, whichever is greater,

$S_1$  = overall length of stiffener between support points, in metres,

and  $K_c$  depends upon the type and position of the material as follows:—

(1) For mild steel

$K_c = 2,5$  mm irrespective of position.

(2) For solid stainless steel and stainless clad steel of:

(a) Bulkheads exposed to the cargo on both sides, e.g. single plate transverse bulkheads and centre-line bulkheads:

$K_c = 2$  mm for solid stainless steel,  
= 2,25 mm for stainless clad steel.

(b) Bulkheads exposed to the cargo on one side and dry on the other side (or coated in a water ballast tank), e.g. longitudinal cofferdam bulkheads adjacent to the shell, top of tanks (or exposed decks) or cofferdam transverse bulkheads with one side in a dry space:

$K_c = 1,0$  mm for solid stainless steel,  
= 1,5 mm for stainless clad steel.

(c) Bulkheads exposed to the cargo on one side and to water ballast on the opposite side, e.g. those items mentioned in (b), but which form the boundaries of both ballast and cargo tanks (*see also R (J) 404*):

$K_c = 1,0$  mm for solid stainless steel,  
= 2,0 mm for stainless clad steel.

If the mild steel side of stainless clad plating is suitably coated,  $K_c$  may be 1,5 mm.

(d) Tank bottoms where the underside is accessible and dry:

$K_c = 1,5$  mm for solid stainless steel,  
= 2,0 mm for stainless clad steel.

(e) Tank bottoms where the underside is accessible and in contact with water ballast (*see R (J) 404*):

$K_c = 1,5$  mm for solid stainless steel,  
= 2,5 mm for stainless clad steel.

(f) Tank bottoms where the underside is inaccessible due to presence of integral heating ducts:

$K_c = 2,0$  mm for solid stainless steel,  
= 3,0 mm for stainless clad steel.

#### Minimum Thickness

509 In no case is the thickness of the plating of crowns and boundary bulkheads of cargo tanks to be less than either:—

$$(1) t = 0,004s \sqrt{h} + K_c \text{ mm}$$

unless  $\frac{1000S_1}{s}$  is less than 4, when the thickness



obtained from the above formula is to be multiplied by the factor:—

$$1,1 - \frac{s}{2500S_1}$$

where  $s$  and  $S_1$  are as defined in 508, and  $h$  = half the vertical distance, in metres, from a point one-third of the height of the plate above its lower edge to the test head as defined in 601,

- or (2) D 50 without correction for relative density, and using a head as defined in D 5001, whichever is the greater.

**510** The minima given in 504 may be reduced by  $(2,5 - K_C)$  mm according to the locations in 508, but in no case is the final overall thickness to be less than 7 mm. See also 513.

**511** The thickness of clad steel includes the cladding, and the thickness of the cladding itself is to be at least 1,5 mm at the tank sides and top and 2,0 mm at the tank bottom.

**512** Heating ducts integral with tanks constructed from solid stainless steel plating may be of mild steel only where a thermal fluid of a type which is non-corrosive to steel is used for the heating medium. If fresh water is used then means of monitoring for the presence of rust should be provided.

**513** Where high proof solid stainless steels are used, special consideration will be given to the scantlings in relation to the material properties, subject to an overall minimum for the thickness of plating of 6,5 mm for the top and sides of tanks and 7,0 mm for the bottoms of tanks.

#### Stiffeners

**514** The scantlings of cargo tank bulkhead stiffeners and corrugations are to be derived from D 19 using the appropriate cargo relative density.

#### Minimum Scantlings

**515** For crowns and boundary bulkheads of cargo tanks, the scantlings of the stiffeners are not to be less than obtained from either:—

- (1) D 19 using a relative density of 1,025 and  $h$  equal to half of the distance, in metres, from the mid-point of span to the test head as required by 601, or (2) D 50 without correction for relative density, and using a head as defined in D 5001, whichever is the greater.

#### Welding inside Cargo Tanks

**516** All fillet welds in cargo tanks are to be double continuous.

- (a) Cargo tanks for type A cargoes. All boundary connections of bulkheads are to be formed by complete penetration welds.  
(b) Cargo tanks for type B cargoes. All boundary connections of bulkheads are to be formed either by complete penetration welds or by fillet welds having a weld factor of 0,44.  
(c) Cargo tanks for type C cargoes. All boundary connections of bulkheads may be formed by welding complying with the requirements of Table D 32.1 for cargo tank bulkheads on oil tankers.

To prevent inter-tank leakage, where longitudinal stiffeners pass continuously through bulkheads, a scallop, the ends of which are to be carefully welded all round, is to be arranged in each longitudinal stiffener adjacent to the bulkhead. Alternatively, complete penetration welds are to be arranged at the connection of each longitudinal stiffener to adjacent plating for a minimum distance of 150 mm on each side of bulkheads. This requirement does not apply to deck stiffening.

#### Section 6

##### TESTING

**601** The requirements of D 52 apply, except that each cargo tank bulkhead is to be hydraulically tested by filling suitably located tanks, cofferdams or double bottoms with water. The test head is to be not less than 2,45 m above the highest point of the tank excluding hatchways, nor less than  $2,0 \times \rho$  m above the top of the tank, where  $\rho$  is the relative density of the intended cargo. The test may be carried out with the ship afloat.

#### Quality Control

**602** The following requirements are intended to supplement the amount of non-destructive testing normally carried out by the shipyard:—

- (a) All butt weld crossings of cargo tank bulkheads which are made on the berth are to be radiographed.  
(b) Where longitudinals stop at bulkheads, a minimum of 10 per cent of the bulkhead boundary connection is to be crack detected.



- (c) Where longitudinal stiffeners pass continuously through the bulkhead, 100 per cent of the bulkhead boundaries on the bottom 10 per cent of the depth of the bulkhead is to be crack detected in addition to the requirements of (b) above.

## Section 7

### VENTILATION OF CARGO HANDLING SPACES AND SPACES ADJACENT TO CARGO TANKS

**701** Permanent mechanical ventilation is to be provided for all enclosed spaces containing pumps, valves or piping, used for controlling loading, discharging and gas freeing. The ventilation system for such spaces is to be independent of all other systems.

**702** In below-deck pump rooms the ventilation system is to be of the mechanical extraction type. The ducting is to be arranged to permit extraction from both above and below the floor plates and from communicating pipe tunnels (if fitted). The upper intake should be arranged at a height of 2,15 m above the floor plates, and is to be provided with a damper capable of being opened or closed from the weather deck and the lower platform level.

**703** The vent exits from pump rooms are to discharge at least 10 m away from windows and access openings to accommodation. The height of vent inlets and exits is not to be less than 4,5 m above the tank deck. Regard is to be taken of the positions of cargo tank vent exits when locating the inlets for pump room vents. (For distance from mechanical ventilation inlets see R (J) 1305.

**704** The mechanical ventilation system is to be capable of being operated from outside the compartment being ventilated, and a notice is to be fixed near the entrance stating that no person is to enter the space until the ventilation system has been in operation for at least 15 minutes.

**705** Other spaces which contain cargo piping, valves, etc., to which regular access is not normally required for operational purposes, also spaces adjacent to cargo tanks, are to be fitted with means of attaching portable mechanical ventilating equipment. The equipment is to be capable of circulating sufficient air to the compartment concerned to give at least 15 air changes per hour. Alternatively, if permanent ventilating equipment with suitable ducting is employed for such spaces, a minimum of 8 air changes per hour will be accepted.

**706** For ships to be classed 100A1 chemical tanker—Type A (cargoes in Tables R (J) 1, R (J) 2 and R (J) 3), pump room ventilation is to consist of not less than 45 air changes per hour, based on the gross volume of the space including access trunking and communicating pipe tunnels (if fitted).

**707** For ships to be classed 100A1 chemical tanker—Type B (cargoes in Tables R (J) 2 and R (J) 3), pump room ventilation is to consist of not less than 30 air changes per hour based on the gross volume of the space including access trunking and communicating pipe tunnels (if fitted).

**708** For ships to be classed 100A1 chemical tanker—Type C (cargoes in Table R (J) 3), pump room ventilation is to consist of not less than 20 air changes per hour based on the gross volume of the space including access trunking and communicating pipe tunnels (if fitted), and the distances and heights of vents given in 703 are not generally applicable.

## Section 8

### VAPOUR DETECTION

**801** For the purpose of vapour detection, a permanently fixed system or portable equipment is to be provided to safely obtain vapour samples from all enclosed spaces containing cargo pumps, pipes and valves regularly used by personnel.

**802** Where a fixed system is fitted, a sufficient number of sampling points are to be provided to give a representative coverage of the space concerned. Arrangements of fixed systems are to be such that there is no possibility of vapour entering a non-dangerous space.

**803** Portable detection equipment is to be provided for use in other spaces adjacent to cargo tanks, e.g. cofferdams, double bottoms, tunnels, etc.

**804** Two sets of portable instruments for detection (and measurement where practicable) of the specific vapours in question are to be provided for the following:—

- (a) flammable vapours,
- (b) toxic vapours,
- (c) oxygen content.

If instruments are provided which combine some of these functions, then the number of such instruments required may be appropriately reduced.



**Section 9****FIRE FIGHTING IN THE CARGO TANK AREA**

**901** Fire fighting equipment suitable for all types of cargoes being carried is to be carried on board.

**902** A fixed installation, or combination of installations, is to be provided for fire fighting in the cargo tanks and in the tank deck area. A nozzle suitable for spraying water is to be provided for use with each hose on the tank deck.

**903** If the vessel is designed to supply inert gas for permanent inerting of all cargo spaces, consideration will be given to acceptance of such a fixed system as an alternative for the protection of cargo tanks, provided that there is sufficient capacity.

**904** Fixed installations for fire fighting on the deck shall be capable of reaching all parts of the tank deck.

**905** Cargo pump rooms are to be provided with a fixed remote controlled fire extinguishing system. In addition, two portable extinguishers of approved type are to be provided in each space.

**Protective Clothing**

**906** Protective clothing for fire fighting, also equipment for protection of crew engaged in loading and discharging operations and equipment permitting personnel to enter gas-filled compartments, are to be in accordance with the requirements of the National Authority.

**PART 3****PUMPING AND PIPING ARRANGEMENTS****General**

For ships which are intended to carry the cargoes listed in Tables R (J) 1 and R (J) 2, the following requirements, and the requirements of E 11, irrespective of the flash point of the cargo, are to be complied with where applicable. *See also* R (J) 105.

For ships which are intended to carry the cargoes listed in Table R (J) 3, the requirements of E 11, irrespective of the flash point of the cargo, are to be complied with where applicable. *See also* R (J) 105.

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**Section 10****PLANS**

**1001** The following diagrammatic plans are to be submitted for consideration, in addition to those required by E 101, where applicable:—

Pumping arrangements at forward and after ends of the ship.

Drainage arrangements of cofferdams and pump rooms and other compartments within the range of, and adjacent to, the cargo tanks.

General arrangement of cargo piping in tanks, on deck and in pump rooms.

Cargo tank venting and sounding arrangements.

Arrangements of inert gas system (where fitted), and arrangements for gas freeing of cargo tanks and cargo handling systems.

Arrangement of cargo heating systems (where fitted).

A general arrangement of the ship showing the location of the controls and instruments.

Arrangements of the control station(s) showing layout of controls and instruments.

Details of controls and instruments.

**Section 11****GENERAL REQUIREMENTS****Materials**

**1101** All materials used in the pumping and piping systems are to be suitable for use with the intended cargoes.

Protective coating of pipes of non-corrosion resistant material would not normally be acceptable for corrosive cargoes.

**Design**

**1102** All piping, valves and fittings are to be suitable for the maximum pressure to which the system can be subjected, but not, in any case, less than a pressure of 1,03 N/mm<sup>2</sup> (10,5 kgf/cm<sup>2</sup>).

Piping subject to pressure is to be of seamless or other approved type and is to comply with the requirements of E 5.

**1103** Pumping and piping systems, including the cargo pumps, are to be made and installed under survey.



**Ballast Tanks and Void Spaces**

**1104** Clean ballast tanks and void spaces within the range of the cargo tanks are not to be connected to cargo pumps or have any connections to the cargo system. A separate ballast/bilge pump is to be provided for dealing with the contents of these spaces. This pump is to be located in the cargo pump room or other suitable space within the range of the cargo tanks.

**1105** Consideration will be given to connecting double bottom and/or wing tanks, which are in the range of the cargo tanks, to pumps in the machinery space where the tanks are completely separated from the cargo tanks by cofferdams, heating ducts or containment spaces, etc.

**1106** Bilge, ballast and oil fuel lines, etc., which are led to pumps in the machinery space, or to other spaces outside the cargo tank range, are not to pass through cargo tanks, although, in general no objection will be made to these lines being led through the clean ballast or void tank spaces within the range of the cargo tanks.

**1107** Air and sounding pipes to wing and double bottom tanks which are adjacent to cargo tanks are to be led to the open deck and are not to pass through cargo tanks.

**1108** Arrangements are to be provided to enable double bottom tanks situated below cargo tanks to be filled with water ballast to assist in the gas freeing of these tanks.

**Pump Room Drainage**

**1109** Below-deck pump room bilge systems for cargoes listed in Table R (J) 1 are to be capable of being operated from the weather deck.

**Section 12****CARGO HANDLING SYSTEM****General**

**1201** Standby means for pumping out each cargo tank are to be provided.

**1202** Where cargo tanks are provided with single deep well pumps, or submerged pumps, it will be necessary to provide alternative means for emptying the tanks in the event of the failure of a pump.

Portable submersible pumps may be provided on board for this purpose, but the arrangements are to be such that a portable pump could be safely introduced into a full or part-full tank. Details of the arrangements are to be submitted.

**Location of Cargo Pumps**

**1203** Where column 8 of Table R (J) 1 cross-refers to this paragraph, the cargo pumps are to be located in the tanks or on deck.

**Cargo Segregation**

**1204** Isolation of piping systems which serve tanks containing incompatible cargoes (*see* R (J) 309 to R (J) 312) are to be made by means of removable pipe lengths and blank flanges. Isolating shut-off valves, single or double, or spectacle flanges are not acceptable as equivalent arrangements.

Cargo piping is not to be led through any tank containing a cargo which is incompatible with that contained in the tank served by such piping unless it is encased in a pipe tunnel.

**Connections to Cargo Tanks**

**1205** Cargo tank deck filling connections are to be provided with pipes internal to the tanks and led to the bottom of the tanks.

**1206** Where cargo suction and/or filling lines are led through cargo tanks, or through other spaces situated below the weather deck, the connection to each tank is to be provided with a valve situated inside the tank and capable of being operated from the deck.

In the case of cargo tanks which are located adjacent to below-deck pump rooms, or pipe tunnels, the deck operated valves may be located in these spaces at the bulkhead.

In any case, however, not less than two isolating shut-off valves are to be provided in the pipe lines between the tanks and the cargo pumps.

**1207** Pumps which are connected to the cargo system or tanks, directly or indirectly, are not to be connected to fire mains or pipe lines which are connected to pumps in the machinery space.

**1208** Means are to be provided to enable the contents of the cargo lines and pumps to be drained to a cargo tank or other suitable tank.

Pump room drain tanks are to be of the closed type with air and sounding pipes led to the open deck.

**Tank Openings**

**1209** Cargo tank access hatches and all other openings to cargo tanks, such as ullage and tank cleaning openings and restricted sounding devices (*see* R (J) 1405), are to be located on the weather deck.



**Remote Control Valves**

**1210** Valves on deck and in pump rooms which are provided with remote control, are, in general, to be capable of local manual operation independent of the remote operating mechanism.

**1211** Where the valves and their actuators are located inside the cargo tanks, two separate suctions are to be provided in each tank.

**1212** All actuators are to be of a type which will prevent the valves from opening inadvertently in the event of the loss of pressure in the operating medium.

Indication is to be provided at the remote control station showing whether the valve is open or shut.

**1213** Materials of construction of the actuators and piping inside the cargo tanks are to be suitable for use with the intended cargoes.

**1214** Compressed air is not to be used for operating actuators inside cargo tanks.

**1215** The actuator operating medium in hydraulic systems is to have a flash point of 60°C or above (closed cup test) and is to be compatible with the intended cargoes.

**1216** The design of the actuators is to be such that contamination of the operating medium with cargo liquid cannot take place under normal operating conditions.

Where the operating medium is oil, or other fluid, the supply tank is to be located as high as practicable above the level of the top of the cargo tanks, and all actuator supply lines are to enter the cargo tanks through the highest part of the tanks. Furthermore, the supply tank is to be of the closed type with an air pipe led to a safe space on the open deck and fitted with a flameproof wire gauze diaphragm at its open end. This tank is also to be fitted with a high and low level audible and visible alarm, and means are to be provided for detecting the presence of cargo liquid in the operating medium.

**1217** It is recommended that for remote control valves, not arranged for manual operation, emergency means be provided for operating the valve actuators in the event of damage to the main hydraulic circuits on deck. In the case of valves located inside cargo tanks this could be achieved by ensuring that the supply lines to the actuators are led vertically inside the tanks from deck, and that connections, with the necessary isolating valves, are provided on deck for coupling to a portable pump carried on board.

**Cargo Handling Controls**

**1218** Electrical measuring, monitoring control and communication circuits located in dangerous spaces are to be intrinsically safe.

**1219** The handling controls and instruments are to be arranged for safe and easy operation. They may be grouped at a number of control stations or at one main control station.

**1220** A satisfactory means of communication is to be provided between cargo handling stations, open deck, the bridge and the machinery space.

**1221** The cargo handling controls and instrumentation are, so far as possible, to be separate from the propulsion and auxiliary machinery controls and instrumentation.

**Section 13****CARGO TANK VENTING ARRANGEMENTS****General**

**1301** Each cargo tank is to be fitted with a vapour pipe (or pipes) led from the highest part (or parts) of the tank and connected through pressure vacuum valves to vapour lines led up the mast or other suitable posts.

The outlets are to be arranged to discharge the vapour in an upward vertical direction and are to be fitted with a readily removable flameproof wire gauze diaphragm protected from the weather.

**1302** Individual vents may be combined into a common riser, provided that regard is given to cargo segregation requirements.

**1303** For the cargoes listed in Table R (J) 1, connections for returning the vapour to shore when loading cargo are to be provided.

**1304** Suitable drainage arrangements are to be provided in the vapour lines.

**Location of Vapour Outlets**

**1305.** The height of vapour outlets is to be not less than 4 m above the weather deck or above the fore and aft gangway if fitted within 4 m of the gangway. The height may be reduced to 2,5 m where the vapour outlets are fitted with an approved type of high velocity venting head. Further, the vapour outlets are also to be arranged not less than 10 m from the nearest air intakes or openings to accommodation and enclosed working spaces and to possible sources of ignition.

For electrical requirements, see M 16.



**1306** For certain cargoes, as indicated in column 8 of Table R (J) 1 and column 7 of Table R (J) 2, the height of vapour outlets are not to be less than 6 m above the weather deck or above the fore and aft gangway if fitted within 6 m of the gangway. The height may be reduced to 4 m where the vapour outlets are fitted with an approved type of high velocity venting head. Further, the vapour outlets are also to be arranged not less than 15 m from the nearest air intakes or openings to accommodation and enclosed working spaces and to possible sources of ignition.

For electrical requirements, *see* M 16.

**1307** The sizes of the vapour pipes and associated valves are to be sufficient to ensure that the cargo tanks will not be subject to over-pressure during loading or under-pressure when discharging.

When sizing the vapour lines, the quantity of vapour liberated from the cargo during loading is to be taken into consideration as well as the maximum loading rate.

**1308** The pressure vacuum valves may be provided with by-pass valves for use when loading cargo.

**1309** Where the vacuum side of a pressure vacuum valve draws direct from the atmosphere, the inlet from the atmosphere is to be provided with a flameproof wire gauze diaphragm.

#### Vacuum Relief

**1310** Where the cargo is required to be carried under an inert gas blanket, vacuum relief is to be obtained from a supply of inert gas. (*See also* Inert Gas Systems, R (J) 16.)

### Section 14

#### CARGO TANK LEVEL GAUGING EQUIPMENT

**1401** Each cargo tank is to be fitted with suitable means for ascertaining the liquid level in the tank.

**1402** Closed sounding devices of an approved type, which do not permit the escape of cargo to the atmosphere, are to be fitted to those tanks which are intended to carry the cargoes listed in Table R (J) 1.

**1403** Where indicated in column 8 of Table R (J) 1, the tanks are to be provided with a high level audible and visible alarm.

**1404** In addition to the high level alarm required by 1403, the tanks of certain cargoes, as indicated in column 8

of Table R (J) 1, will require to be provided with an independent high level alarm device giving audible and visible warning of over-filling and capable of closing the tank filling valve. Alternative means of avoiding accidental spillage will be specially considered.

**1405** Restricted sounding devices, which may permit a limited amount of vapour to escape to the atmosphere when being used, would be accepted for cargo tanks which are intended to carry the cargoes listed in Table R (J) 2.

The restricted sounding device should be so designed as to minimize sudden release of vapour under pressure and the possibility of liquid spillage on deck.

**1406** Proposals to use indirect sounding devices which do not penetrate the tank plating will be specially considered.

### Section 15

#### CARGO HEATING ARRANGEMENTS

##### General

**1501** Where heating systems are provided for the cargo tanks, the following requirements are to be complied with:—

- (a) The heating medium is to be compatible with the cargoes to be heated.
- (b) Isolating shut-off valves are to be provided at the inlet and outlet connections to the heating circuit of each tank.
- (c) A test cock and a connection for either compressed air or inert gas is to be provided for "blowing through" the heating circuits of each tank. The cargo heating circuit should be blown through and hydraulically tested each time before loading a toxic cargo which requires to be heated.
- (d) A higher pressure is to be maintained within the heating circuit than the maximum pressure head which can be exerted by the contents of the cargo tank on the circuit. Alternatively, when the heating circuit is not in use, it may be drained and blanked.
- (e) Heating supply and return lines are not to penetrate the cargo tank plating other than on the top of the tank, and the main lines are to be run above the weather deck.
- (f) Means are to be provided for detecting the presence of chemicals in the return lines.

- (g) Steam heating return lines from cargo tanks which are intended to carry toxic cargoes are to be led to an observation tank located on the open deck. Alternatively, the observation tank may be located in the machinery space provided that it be of the closed type and is fitted with an air pipe led to a safe space on the open deck. Safe means are to be provided to remove contaminated heating medium from the observation tank.

- (h) Means are to be provided for ascertaining the temperature of the cargo in the tanks.

**1502** Proposals to use cargo heating systems which employ thermal oil or hot water will be specially considered.

## Section 16

### INERT GAS SYSTEMS

#### General

**1601** Where it is intended to transport cargoes which require to be carried under an inert gas blanket, and/or where the spaces adjacent to the cargo tanks require to be inerted an approved inert gas system is to be provided on board.

**1602** Where an inert gas system is fitted for the cargo tanks, the arrangements are to comply with the requirements of E 1160 to E 1184, wherever applicable. Consideration will be given to special cases where the arrangements are equivalent to those required by the Rules.

**1603** Where an inert gas system is fitted for the spaces adjacent to the cargo tanks only, the capacity is to be sufficient for dealing with any losses during the voyage. For this purpose inert gas storage vessels are acceptable.

**1604** In all installations the inert gas is to be suitable for use with the cargoes to be carried.

**1605** Means are to be provided for indicating the pressure in the vapour space of each cargo tank and each inerted space.

**1606** Meters are to be provided on board for checking the amount of oxygen in the generated inert gas and in the inerted spaces.

#### Piping Systems

**1607** Where an inert gas system is fitted the following additional requirements are to be complied with:—

- (a) The necessary piping system is to be provided on board for distributing the inert gas, and connections are also to be provided for receiving or returning inert gas to shore.
- (b) Arrangements are to be provided for preventing the back flow of cargo vapour into the inert gas system.
- (c) The arrangements are to be such that spaces being inerted can be individually isolated from the inert gas piping system, and the necessary controls and relief valves, etc., are to be provided for preventing over-pressure in these spaces.
- (d) The piping system serving cargo tanks is to be separate from that serving other spaces, so far as practicable.
- (e) Gas freeing connections between the inert gas system and the cargo piping system are, in general, to be made by means of portable pipes which should be removed when not in use and the connections suitably blanked.

#### Cross-reference

**1608** See also R (J) 8—Vapour Detection.



## PART 4

## TABLES OF CARGOES

## NOTES

- (a) The tables of cargoes have been prepared on considerations of safety. Arrangements for conserving the quality of the cargo are the responsibility of the Owner.
- (b) An **x** in the appropriate column indicates a significant hazard. The absence of an **x**, however, does not mean that no hazard exists under that heading.
- (c) Fire hazard is indicated in column 3 when the flash point (closed cup test) is below 60°C. However, in the last column particulars may be given when the auto-ignition temperature is less than 180°C and/or there is a wide flammable range or high vapour pressure.
- (d) Reactivity with the environment or self-reactivity have not been indicated, since such cargoes would require to be inerted and/or inhibited, as indicated in the last column.
- (e) Chemical Tankers Types A, B and C may carry:—
  - (i) normal petroleum cargoes and mineral oils such as crude oil, fuel oil, diesel oil, lubricating oil and refined spirits such as gasoline, jet fuel, kerosene, etc.
  - (ii) wines or vegetable and edible oils such as castor oil, coconut oil, cotton seed oil, fish oil, latex, olive oil, palm oil, peanut oil, soya bean oil, sperm oil, tall oil, etc.
- (f) Cargoes having a hazard no different from nor greater in degree than the hazards associated with the approved list of cargoes may also be carried in a subject vessel.

TABLE R (J) 1 TYPE A CARGOES (see continuation)

1 NAME FORMULA	2 RELATIVE DENSITY (SG) WHERE OVER 1,025	3 FIRE HAZARD	4 VAPOUR HAZARD	5 SKIN CONTACT HAZARD	6 WATER REAC- TIVITY HAZARD	7 UNSUITABLE MATERIALS	8 ADDITIONAL REQUIREMENTS, INFORMATION, ETC.
ACETIC ACID <chem>CH3COOH</chem>	1,05	x	—	x	—	Mild Steel	Stainless Steel or Alu- minium acceptable
ACETIC ANHYDRIDE <chem>(CH3CO)2O</chem>	1,08	—	x	x	x	Mild Steel	Stainless Steel or Alu- minium acceptable
ACETONE CYANOHYDRIN <chem>(CH3)2C(OH)CN</chem>	—	—	x	x	—	—	Stabilized for shipment. <i>See also</i> 1203, 1403 and 1404
ACETONITRILE <chem>CH3CN</chem>	—	x	x	x	—	Cu	<i>See</i> 1306
ACRYLONITRILE <chem>CH2CHCN</chem>	—	x	x	x	—	Mg Al Zn Cu	Inhibited for shipment. <i>See also</i> 1306 and 1403
ALLYL ALCOHOL <chem>CH2CHCH2OH</chem>	—	x	x	x	—	—	<i>See also</i> 1306, 1403 and 1404
ALLYL CHLORIDE <chem>CH2CHCH2Cl</chem>	—	x	x	x	—	Mild Steel if water present	Boiling point 45°C Nickel acceptable <i>See also</i> 1306, 1403 and 1404
ANILINE <chem>C6H5NH2</chem>	—	—	x	x	—	—	<i>See</i> 1306, 1403 and 1404
n or iso-BUTYL ACRYLATE <chem>CH2CHCOOC4H9</chem>	—	x	—	x	—	—	Inhibited for shipment
CARBOLIC OIL (containing naphthalene, phenol and cresols)	Abt 1,1	—	x	x	—	—	<i>See</i> 1306, 1403, and 1404
CHLOROHYDRINS (crude)	1,2	x	x	x	—	—	<i>See</i> 1306, 1403 and 1404
CHLOROSULPHONIC ACID <chem>ClSO2OH</chem>	1,77	—	x	x	x	—	Evolves Hydrogen <i>See also</i> 314 (B/5 applies), 1306, 1403 and 1404
CROTONALDEHYDE <chem>CH3CHCHCHO</chem>	—	x	x	x	—	—	<i>See</i> 1306
1,2 DICHLOROPROPANE <chem>CH3CHClCH2Cl</chem>	1,16	x	x	x	—	Al	<i>See</i> 1306



TABLE R (J) 1 TYPE A CARGOES (continued)

1 NAME FORMULA	2 RELATIVE DENSITY (SG) WHERE OVER 1,025	3 FIRE HAZARD	4 VAPOUR HAZARD	5 SKIN CONTACT HAZARD	6 WATER REAC- TIVITY HAZARD	7 UNSUITABLE MATERIALS	8 ADDITIONAL REQUIREMENTS, INFORMATION, ETC.
1,3 DICHLOROPROPENE <chem>CHClCHCH2Cl</chem>	1,23	x	x	x	—	Attacks Mild Steel if water present	See 1306
EPICHLOROHYDRIN <chem>C3H5OCl</chem>	1,18	x	x	x	—	—	See 1306, 1403 and 1404
ETHYLENE DIBROMIDE <chem>CH2BrCH2Br</chem>	2,17	—	x	x	—	—	See 1306 and 1403
ETHYL ACRYLATE <chem>CH2CHCOOC2H5</chem>	—	x	x	x	—	—	Inhibited for shipment
ETHYLENEDIAMINE <chem>NH2CH2CH2NH2</chem>	—	x	—	x	—	Cu	
ETHYLENE DICHLORIDE <chem>CH2ClCH2Cl</chem>	1,26	x	x	—	—	Cu	See 1403
FORMIC ACID <chem>HCOOH</chem>	1,22	—	x	x	—	Mild Steel	Stainless Steel acceptable also Aluminium for concentrations > 98%
METHYL ACRYLATE <chem>CH2CHCOOCH3</chem>	—	x	x	x	—	—	Inhibited for shipment
METHYL METHACRYLATE <chem>CH2C(CH3)COOCH3</chem>	—	x	x	—	—	Cu	Inhibited for shipment
NITRIC ACID (70% AQ SOL and OVER) <chem>HNO3</chem>	1,5	—	x	x	—	Mild Steel	Strong oxidizing agent Stainless Steel acceptable See 1403 and 1404
OLEUM <chem>H2SO4+SO3</chem>	1,98	—	x	x	x	Mild Steel for conc. less than 98%	Mild Steel acceptable for conc. 98% or more Stainless Steel acceptable for all conc. Evolves Hydrogen See also 1403 and 1404

TABLE R (J) 1 TYPE A CARGOES (conclusion)

1 NAME FORMULA	2 RELATIVE DENSITY (80) WHERE OVER 1,025	3 FIRE HAZARD	4 VAPOUR HAZARD	5 SKIN CONTACT HAZARD	6 WATER REAC- TIVITY HAZARD	7 UNSUITABLE MATERIALS	8 ADDITIONAL REQUIREMENTS, INFORMATION, ETC.
PHENOL $C_6H_5OH$	1,05	—	x	x	—	Al Cu Zn	Heated Cargo Freezing point 41°C See 1306, 1403 and 1404
PHOSPHORIC ACID (85%) $H_3PO_4$	1,7	—	—	x	—	Mild Steel	Stainless Steel acceptable or Rubber Linings Heated Cargo Freezing point 23°C
PHOSPHORUS TRICHLORIDE $PCl_3$	1,57	—	x	x	x	Mild Steel Al Zn	Inerted for shipment (Dry Nitrogen) Nickel acceptable
PHOSPHORYL CHLORIDE $POCl_3$	1,67	—	x	x	x	Mild Steel Al Zn	Inerted for shipment (Dry Nitrogen) Nickel acceptable
PROPIONIC ACID $CH_3CH_2COOH$	—	—	—	x	—	Mild Steel	Stainless Steel or Alu- minium acceptable
SULPHURIC ACID $H_2SO_4$	1,84	—	—	x	x	Mild Steel for conc. less than 98%	Mild Steel for conc. 98% or more. Stainless Steel acceptable for conc. below 20% and above 80% at ambient temp.
SULPHUR TRIOXIDE $SO_3$	1,83	—	x	x	x	—	Inhibited for shipment Normal carrying temp. 30°-35°C
TOLYLENE DI-ISOCYANATE $CH_3C_6H_3(NCO)_2$	1,22	—	x	x	x	—	Inerted for shipment (Dry Nitrogen) Normal carrying temp. 20°-25°C



TABLE R (J) 2 TYPE B CARGOES (see continuation)

1 NAME FORMULA	2 RELATIVE DENSITY (SG) WHERE OVER 1,025	3 FIRE HAZARD	4 VAPOUR HAZARD	5 SKIN CONTACT HAZARD	6 UNSUITABLE MATERIALS	7 ADDITIONAL REQUIREMENTS, INFORMATION, ETC.
ADIPONITRILE $\text{CN}(\text{CH}_2)_4\text{CN}$	—	—	x	x	—	
AMMONIA 30% SOL. $\text{NH}_4\text{OH}$	—	—	x	x	Cu Zn Nickel	Absolute vapour pressure at 30°C = 0,109 N/mm <sup>2</sup> (1,11 kgf/cm <sup>2</sup> )
BENZENE $\text{C}_6\text{H}_6$	—	x	x	—	—	706 applies for pump room ventila- tion See 1306
iso-BUTYRALDEHYDE $(\text{CH}_3)_2\text{CHCHO}$	—	x	—	x	—	
n-BUTYRALDEHYDE $\text{CH}_3(\text{CH}_2)_2\text{CHO}$	—	x	—	x	—	
CARBON TETRACHLORIDE $\text{CCl}_4$	1,59	—	x	—	Al Zn	706 applies for pump room ventila- tion See 1306
CHLOROBENZENE $\text{C}_6\text{H}_5\text{Cl}$	1,11	x	x	—	—	
CHLOROFORM $\text{CHCl}_3$	1,48	—	x	—	—	See 1306
p-CRESOLS (pCRESYLIC ACID) (mixed isomers) $\text{CH}_3\text{C}_6\text{H}_4\text{OH}$	1,05	—	—	x	—	Heated cargo Freezing point 20°C–34°C
CUMENE $\text{C}_6\text{H}_5\text{CH}(\text{CH}_3)_2$	—	x	x	—	—	
CREOSOTE	1,10	—	—	x	—	
2,2 DICHLOROETHYL ETHER $\text{ClCH}_2\text{CH}_2\text{OCH}_2\text{CH}_2\text{Cl}$	1,22	—	x	x	—	
DIETHANOLAMINE $(\text{HOCH}_2\text{CH}_2)_2\text{NH}$	1,1	—	—	x	Cu Zn	
DIETHYLAMINE $(\text{C}_2\text{H}_5)_2\text{NH}$	—	x	—	x	Al Cu Zn	

TABLE R (J) 2 TYPE B CARGOES (continued)

1 NAME FORMULA	2 RELATIVE DENSITY (SG) WHERE OVER 1,025	3 FIRE HAZARD	4 VAPOUR HAZARD	5 SKIN CONTACT HAZARD	6 UNSUITABLE MATERIALS	7 ADDITIONAL REQUIREMENTS, INFORMATION, ETC.
DIETHYLENE TRIAMINE $\text{NH}_2\text{CH}_2\text{CH}_2\text{NHCH}_2\text{CH}_2\text{NH}_2$	—	—	—	x	Cu	
DIMETHYLAMINE 40% AQ $(\text{CH}_3)_2\text{NH}$	—	x	x	x	Al Cu Zn	See 1306
DIMETHYLAMINOETHANOL $(\text{CH}_3)_2\text{NCH}_2\text{CH}_2\text{OH}$	—	x	—	x	Cu	
DIMETHYL FORMAMIDE $\text{HCON}(\text{CH}_3)_2$	—	x	—	x	—	
2 ETHYL 3 PROPYL ACROLEIN $\text{CH}_3(\text{CH}_2)_2\text{CHC}(\text{C}_2\text{H}_5)\text{CHO}$	—	x	x	—	—	
ETHYLENE CYANOHYDRIN $\text{CH}_2\text{OHCH}_2\text{CN}$	1,04	x	x	x	—	
FORMALDEHYDE SOL 37% HCHO	1,11	x	x	x	—	
FURFURAL $\text{C}_4\text{H}_3\text{OCHO}$	1,16	x	x	—	—	
FURFURYL ALCOHOL $\text{C}_4\text{H}_3\text{OCH}_2\text{OH}$	1,13	—	x	—	Al	
MORPHOLINE $(\text{CH}_2)_4\text{ONH}$	—	x	—	x	Cu Zn	
NITROBENZENE $\text{C}_6\text{H}_5\text{NO}_2$	1,20	—	x	x	—	
PENTACHLOROETHANE $\text{CHCl}_2\text{CCl}_3$	1,68	—	x	—	—	
PROPIONALDEHYDE $\text{C}_2\text{H}_5\text{CHO}$	—	x	—	x	—	Inerted for shipment (Dry Nitro- gen) Boiling point 49°C



TABLE R (J) 2 TYPE B CARGOES (conclusion)

1 NAME FORMULA	2 RELATIVE DENSITY (SG) WHERE OVER 1,025	3 FIRE HAZARD	4 VAPOUR HAZARD	5 SKIN CONTACT HAZARD	6 UNSUITABLE MATERIALS	7 ADDITIONAL REQUIREMENTS, INFORMATION, ETC.
PYRIDINE (99% conc.) $\text{N}(\text{CH})_4\text{CH}$	—	x	—	x	Cu	
STYRENE MONOMER $\text{C}_6\text{H}_5\text{CHCH}_2$	—	x	x	—	Cu	Inhibited for shipment
TETRACHLOROETHANE $\text{CHCl}_2\text{CHCl}_2$	1,59	—	x	—	Cu	
TETRAHYDROFURAN $(\text{C}_2\text{H}_4)_2\text{O}$	—	x	x	—	—	Inhibited for shipment
TRIETHYLENE TETRAMINE $\text{NH}_2(\text{C}_2\text{H}_4\text{NH})_3\text{H}$	—	—	—	x	Al Cu Zn	
iso-VALERALDEHYDE $(\text{CH}_3)_2\text{CHCH}_2\text{CHO}$	—	x	x	x	—	
n-VALERALDEHYDE $\text{CH}_3(\text{CH}_2)_3\text{CHO}$	—	x	x	x	—	

TABLE R (J) 3 TYPE C CARGOES (see continuation)

1 NAME FORMULA	2 RELATIVE DENSITY (SG) WHERE OVER 1,025	3 FIRE HAZARD	4 UNSUITABLE MATERIALS	5 ADDITIONAL REQUIREMENTS, INFORMATION, ETC.
ACETONE $\text{CH}_3\text{COCH}_3$	—	X	—	
AMYL ACETATE-iso $\text{CH}_3\text{COO}(\text{CH}_2)_2\text{CH}(\text{CH}_3)_2$	—	X	—	
AMYL ACETATE-sec $\text{CH}_3\text{COOCH}(\text{CH}_3)\text{C}_3\text{H}_7$	—	X	—	
AMYL ACETATE-n $\text{CH}_3\text{COOC}_5\text{H}_{11}$	—	X	—	
AMYL ALCOHOL-n $\text{CH}_3(\text{CH}_2)_4\text{OH}$	—	X	—	
AMYL ALCOHOL-p, iso $(\text{CH}_3)_2\text{CHCH}_2\text{CH}_2\text{OH}$	—	X	—	
AMYL ALCOHOL-sec, n $(\text{CH}_3\text{CH}_2)_2\text{CHOH}$	—	X	—	
AMYL ALCOHOL-sec, iso $(\text{CH}_3)_2\text{CHCHOHCH}_3$	—	X	—	
AMYL ALCOHOL-tert $(\text{CH}_3)_2\text{C}_2\text{H}_5\text{COH}$	—	X	—	
ASPHALT	Up to 1,10	See column 5	—	Heated cargo Flash point depends upon grade
BUTYL ACETATE-iso $\text{CH}_3\text{COOCH}_2\text{CH}(\text{CH}_3)_2$	—	X	—	
BUTYL ACETATE-n $\text{CH}_3\text{COOC}_4\text{H}_9$	—	X	—	
BUTYL ACETATE-sec $\text{CH}_3\text{COOCH}(\text{CH}_3)(\text{C}_2\text{H}_5)$	—	X	—	
BUTYL ALCOHOL-iso $(\text{CH}_3)_2\text{CHCH}_2\text{OH}$	—	X	—	
BUTYL ALCOHOL-n $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH}$	—	X	—	



TABLE R (J) 3 TYPE C CARGOES (continued)

1 NAME FORMULA	2 RELATIVE DENSITY (SG) WHERE OVER 1,025	3 FIRE HAZARD	4 UNSUITABLE MATERIALS	5 ADDITIONAL REQUIREMENTS, INFORMATION, ETC.
BUTYL ALCOHOL-sec $\text{CH}_3\text{CH}_2\text{CHOHCH}_3$	—	x	—	
BUTYL ALCOHOL-tert $(\text{CH}_3)_2\text{COHCH}_3$	—	x	—	
BUTYL BENZYL PHTHALATE $\text{C}_4\text{H}_9\text{COOC}_6\text{H}_4\text{COOCH}_2\text{C}_6\text{H}_5$	1,12	—	—	
BUTYL DIGLYCOL ACETATE $\text{C}_4\text{H}_9\text{O}(\text{CH}_2)_2\text{O}(\text{CH}_2)_2\text{OCOCH}_3$	—	—	—	
BUTYL ETHER $(\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2)_2\text{O}$	—	x	—	Inhibited for shipment
BUTYL METHACRYLATE $\text{CH}_2\text{C}(\text{CH}_3)\text{COOC}_4\text{H}_9$	—	x	—	Inhibited for shipment
BUTYL PHTHALATE $\text{C}_6\text{H}_4(\text{COOC}_4\text{H}_9)_2$	1,05	—	—	
CAMPHOR OIL	1,04 max.	x	—	
CAUSTIC SODA 55% $\text{NaOH}$	1,53	—	Cu Al Zn	If heated, temp. not to exceed 55°C
CYCLOHEPTANE $\text{C}_7\text{H}_{14}$	—	x	—	
CYCLOHEXANE $\text{C}_6\text{H}_{12}$	—	x	—	
CYCLOHEXANOL $\text{C}_6\text{H}_{11}\text{OH}$	—	—	—	
CYCLOHEXANONE $\text{C}_6\text{H}_{10}\text{O}$	—	x	—	
p-CYMENE $\text{CH}_3\text{C}_6\text{H}_4\text{CH}(\text{CH}_3)_2$	—	x	—	
n-DECYL ALCOHOL $\text{CH}_3(\text{CH}_2)_8\text{CH}_2\text{OH}$	—	—	—	
iso-DECYL ALCOHOL $\text{C}_{10}\text{H}_{21}\text{OH}$	—	x	—	

TABLE R (J) 3 TYPE C CARGOES (continued)

1 NAME FORMULA	2 RELATIVE DENSITY (80) WHERE OVER 1,025	3 FIRE HAZARD	4 UNSUITABLE MATERIALS	5 ADDITIONAL REQUIREMENTS, INFORMATION, ETC.
DIACETONE ALCOHOL $\text{CH}_3\text{COCH}_2\text{C}(\text{CH}_3)_2\text{OH}$	—	x	—	
DIBUTYLAMINE $(\text{C}_4\text{H}_9)_2\text{NH}$	—	x	—	
1,2 DICHLOROBENZENE $\text{C}_6\text{H}_4\text{Cl}_2$	1,31	—	—	
DICYCLOPENTADIENE $\text{C}_{10}\text{H}_{12}$	—	x	—	
DIETHYLBENZENE $\text{C}_6\text{H}_4(\text{C}_2\text{H}_5)_2$	—	x	—	
DIETHYLENE GLYCOL $\text{CH}_2\text{OHCH}_2\text{OCH}_2\text{CH}_2\text{OH}$	1,12	—	—	
DIETHYLENE GLYCOL METHYL ETHER $\text{CH}_3\text{OCH}_2\text{CH}_2\text{OCH}_2\text{CH}_2\text{OH}$	1,04	—	—	
DIETHYLENE GLYCOL MONOBUTYL ETHER $\text{C}_4\text{H}_9\text{OCH}_2\text{CH}_2\text{OCH}_2\text{CH}_2\text{OH}$	—	—	—	
DIETHYLENE GLYCOL MONOETHYL ETHER $\text{CH}_3\text{CH}_2\text{OCH}_2\text{CH}_2\text{OCH}_2\text{CH}_2\text{OH}$	1,03	—	—	
DIISOBUTYLENE Compound of $\text{C}_8\text{H}_{16}$	—	x	—	
DIISOPROPANOLAMINE $(\text{CH}_3\text{CHOHCH}_2)_2\text{NH}$	—	—	Cu	Heated Cargo Freezing point 40°C
DIISOBUTYLKETONE $[(\text{CH}_3)_2\text{CHCH}_2]_2\text{CO}$	—	x	—	
DIISOCTYL PHTHALATE $\text{C}_6\text{H}_4(\text{COOC}_8\text{H}_{17})_2$	—	—	—	
DIPENTENE $\text{C}_{10}\text{H}_{16}$	—	x	—	
DIPROPYLENE GLYCOL $(\text{CH}_3\text{CHOHCH}_2)_2\text{O}$	—	—	—	
DIPROPYLENE GLYCOL METHYL ETHER $\text{CH}_3\text{OC}_3\text{H}_6\text{OC}_3\text{H}_6\text{OH}$	—	—	—	
DODECYL ALCOHOL $\text{CH}_3(\text{CH}_2)_{11}\text{OH}$	—	—	—	
DODECYL BENZENE $\text{C}_{12}\text{H}_{25}\text{C}_6\text{H}_5$	—	—	—	



TABLE R (J) 3 TYPE C CARGOES (continued)

1 NAME FORMULA	2 RELATIVE DENSITY (80) WHERE OVER 1,025	3 FIRE HAZARD	4 UNSUITABLE MATERIALS	5 ADDITIONAL REQUIREMENTS, INFORMATION, ETC.
ETHYL ACETATE $\text{CH}_3\text{COOC}_2\text{H}_5$	—	x	—	
ETHYL ALCOHOL $\text{C}_2\text{H}_5\text{OH}$	—	x	—	
ETHYL BENZENE $\text{C}_6\text{H}_5\text{C}_2\text{H}_5$	—	x	—	
ETHYL CYCLOHEXANE $\text{C}_2\text{H}_5\text{C}_6\text{H}_{11}$	—	x	—	
2-ETHYL HEXYL ACRYLATE $\text{CH}_2\text{CHCO}_2\text{CH}_2\text{CH}(\text{C}_2\text{H}_5)\text{C}_4\text{H}_9$	—	—	—	
ETHYLENE CARBONATE $(\text{CH}_2\text{O})_2\text{CO}$	1,32	—	—	
ETHYLENE GLYCOL $\text{CH}_2\text{OHCH}_2\text{OH}$	1,13	—	—	
ETHYLENE GLYCOL MONOBUTYL ETHER $\text{C}_4\text{H}_9\text{OCH}_2\text{CH}_2\text{OH}$	—	x	—	
ETHYLENE GLYCOL MONOBUTYL ETHER ACETATE $\text{C}_4\text{H}_9\text{O}(\text{CH}_2)_2\text{OOCCH}_3$	—	—	—	
ETHYLENE GLYCOL MONOETHYL ETHER $\text{CH}_2\text{OHCH}_2\text{OC}_2\text{H}_5$	—	x	—	
ETHYLENE GLYCOL MONOETHYL ETHER ACETATE $\text{CH}_3\text{COOCH}_2\text{CH}_2\text{OC}_2\text{H}_5$	—	x	—	
ETHYLENE GLYCOL MONOMETHYL ETHER $\text{CH}_3\text{OCH}_2\text{CH}_2\text{OH}$	—	x	—	
ETHYLENE GLYCOL MONOPHENYL ETHER $\text{C}_6\text{H}_5\text{O}(\text{CH}_2)_2\text{OH}$	—	—	—	
2-ETHYL HEXANOL $\text{CH}_3(\text{CH}_2)_3\text{CHC}_2\text{H}_5\text{CH}_2\text{OH}$	—	—	—	
GLYCERINE (GLYCEROL) $\text{C}_3\text{H}_5(\text{OH})_3$	1,26	—	—	May require heating Melting point 18°C

TABLE R (J) 3 TYPE C CARGOES (continued)

1 NAME FORMULA	2 RELATIVE DENSITY (SG) WHERE OVER 1,025	3 FIRE HAZARD	4 UNSUITABLE MATERIALS	5 ADDITIONAL REQUIREMENTS, INFORMATION, ETC.
HEPTANE-n $\text{CH}_3(\text{CH}_2)_5\text{CH}_3$	—	X	—	
HEPTENE (MIXED ISOMERS) $\text{C}_7\text{H}_{14}$	—	X	—	
HEPTYL ALCOHOL-n $\text{CH}_3(\text{CH}_2)_5\text{CH}_2\text{OH}$	—	X	—	
HEXANE-iso $\text{CH}_3(\text{CH}_2)_2\text{CH}(\text{CH}_3)_2$	—	X	—	
HEXENE-1 $\text{CH}_2\text{CH}(\text{CH}_2)_3\text{CH}_3$	—	X	—	
HEXYL ALCOHOL-n $\text{CH}_3(\text{CH}_2)_4\text{CH}_2\text{OH}$	—	X	—	
HEXYLENE GLYCOL $(\text{CH}_2)_2\text{COHCH}_2\text{CHOHCH}_3$	—	—	—	
METHYL ACETATE $\text{CH}_3\text{COOCH}_3$	—	X	—	
METHYL ALCOHOL $\text{CH}_3\text{OH}$	—	X	Mg	Wide flammable range
METHOXYTRIGLYCOL $\text{CH}_3\text{O}(\text{C}_2\text{H}_4\text{O})_3\text{H}$	1,05	—	—	
METHYL AMYL ACETATE $\text{CH}_3\text{COOCH}(\text{CH}_3)\text{CH}_2\text{CH}(\text{CH}_3)_2$	—	X	—	
METHYL AMYL ALCOHOL $(\text{CH}_3)_2\text{CHCH}_2\text{CH}(\text{CH}_3)\text{OH}$	—	X	—	
METHYL ETHYL KETONE $\text{CH}_3\text{COC}_2\text{H}_5$	—	X	—	
METHYL ISOBUTYL KETONE $\text{CH}_3\text{COCH}_2\text{CH}(\text{CH}_3)_2$	—	X	—	
MONOETHANOLAMINE $\text{HOCH}_2\text{CH}_2\text{NH}_2$	—	—	Cu Zn	
2-METHYL 5-ETHYL PYRIDINE $\text{CH}_3\text{C}_5\text{H}_3\text{NC}_2\text{H}_5$	—	—	—	
MONOISOPROPANOLAMINE $\text{CH}_3\text{CHOHCH}_2\text{NH}_2$	—	—	—	



TABLE R (J) 3 TYPE C CARGOES (continued)

1 NAME FORMULA	2 RELATIVE DENSITY (SG) WHERE OVER 1,025	3 FIRE HAZARD	4 UNSUITABLE MATERIALS	5 ADDITIONAL REQUIREMENTS, INFORMATION, ETC.
NAPHTHA (PETROLEUM)	—	x	—	
NAPHTHA (SOLVENT) (COAL TAR)	—	x	—	
NAPHTHALENE (MOLTEN) $C_{10}H_8$	1,15	x	—	Melting point 80°C Fire hazard relates to carriage temp. above flash point
NITROETHANE $CH_3CH_2NO_2$	1,05	x	Cu	
NITROMETHANE $CH_3NO_2$	1,14	x	—	
NITROPROPANE-1 $CH_3CH_2CH_2NO_2$	—	x	Cu	
NITROPROPANE-2 $(CH_3)_2CHNO_2$	—	x	Cu	
NONANE-n $C_9H_{20}$	—	x	—	
i-NONENE (NONYLENE) $C_9H_{18}$	—	—	—	
NONYL ALCOHOL $C_9H_{19}OH$	—	—	—	
NONYL PHENOL $C_9H_{19}C_6H_4OH$	—	—	—	Normally heated up to a max. of 40°C
iso-OCTANE $C_8H_{18}$	—	x	—	
OCTENE $C_8H_{16}$	—	x	—	
OCTYL ALCOHOL $CH_3(CH_2)_7CH_2OH$	—	—	—	

TABLE R (J) 3 TYPE C CARGOES (continued)

1 NAME FORMULA	2 RELATIVE DENSITY (SG) WHERE OVER 1,025	3 FIRE HAZARD	4 UNSUITABLE MATERIALS	5 ADDITIONAL REQUIREMENTS, INFORMATION, ETC.
PERCHLOROETHYLENE $C_2Cl_4$	1,62	—	—	
POTASSIUM HYDROXIDE 50% KOH	1,54	—	Al Zn	
PROPYL ACETATE-i $CH_3COOCH(CH_3)_2$	—	x	—	
PROPYL ACETATE-n $CH_3OOCCH_2CH_2CH_3$	—	x	—	
PROPYL ALCOHOL-i $(CH_3)_2CHOH$	—	x	—	
PROPYL ALCOHOL-n $C_3H_7OH$	—	x	—	
PROPYLENE GLYCOL $CH_3CHOHCH_2OH$	1,04	—	—	
PROPYLENE GLYCOL MONOMETHYL ETHER $CH_3OCH_2CHOHCH_3$	—	x	—	
TETRAHYDRONAPHTHELENE $C_{10}H_{12}$	—	—	—	
TETRAPROPYLENE $C_{12}H_{24}$	—	x	—	
TOLUENE $C_6H_5CH_3$	—	x	—	
TRICHLOROETHANE 1, 1, 1 $CH_3CCl_3$	1,46	—	Al	Aluminium acceptable if cargo inhibited
TRICHLOROETHYLENE $C_2HCl_3$	1,47	—	—	
TRIDECYL ALCOHOL $C_{12}H_{25}CH_2OH$	—	—	—	
TRIETHANOLAMINE $(HOC_2H_4)_3N$	1,13	—	Cu	
TRIETHYL BENZENE $C_6H_5(CH_2CH_3)_3$	—	—	—	



TABLE R (J) 3 TYPE C CARGOES (conclusion)

1 NAME FORMULA	2 RELATIVE DENSITY (SG) WHERE OVER 1,025	3 FIRE HAZARD	4 UNSUITABLE MATERIALS	5 ADDITIONAL REQUIREMENTS, INFORMATION, ETC.
TRIETHYLENE GLYCOL $C_6H_{14}OH$	1,12	—	—	
TRIPROPYLENE $C_9H_{18}$	—	x	—	
TRIPROPYLENE GLYCOL $C_9H_{20}O_4$	—	—	—	
TRIPROPYLENE GLYCOL MONOMETHYL ETHER $HO(C_3H_6O)_2C_3H_6OCH_3$	—	—	—	
VINYL ACETATE $CH_3COOCHCH_2$	—	x	—	Inhibited for shipment
VINYL TOLUENE $CH_2CHC_6H_4CH_3$	—	x	—	
XYLENE-m $C_6H_4(CH_3)_2$	—	x	—	
XYLENE-o $C_6H_4(CH_3)_2$	—	x	—	
XYLENE-p $C_6H_4(CH_3)_2$	—	x	—	Melting point 13°C
XYLENOL 3,5 $(CH_3)_2C_6H_3OH$	1,04	—	—	Melting point varies May require heating

RECORDS OF THE DISTRICT COURT

Case No.	Plaintiff	Defendant	Amount	Filed	Settled
100-10001	John Doe	Jane Smith	\$100.00	1/1/1910	
100-10002	John Doe	Jane Smith	\$200.00	1/1/1910	
100-10003	John Doe	Jane Smith	\$300.00	1/1/1910	
100-10004	John Doe	Jane Smith	\$400.00	1/1/1910	
100-10005	John Doe	Jane Smith	\$500.00	1/1/1910	
100-10006	John Doe	Jane Smith	\$600.00	1/1/1910	
100-10007	John Doe	Jane Smith	\$700.00	1/1/1910	
100-10008	John Doe	Jane Smith	\$800.00	1/1/1910	
100-10009	John Doe	Jane Smith	\$900.00	1/1/1910	
100-10010	John Doe	Jane Smith	\$1000.00	1/1/1910	
100-10011	John Doe	Jane Smith	\$1100.00	1/1/1910	
100-10012	John Doe	Jane Smith	\$1200.00	1/1/1910	
100-10013	John Doe	Jane Smith	\$1300.00	1/1/1910	
100-10014	John Doe	Jane Smith	\$1400.00	1/1/1910	
100-10015	John Doe	Jane Smith	\$1500.00	1/1/1910	
100-10016	John Doe	Jane Smith	\$1600.00	1/1/1910	
100-10017	John Doe	Jane Smith	\$1700.00	1/1/1910	
100-10018	John Doe	Jane Smith	\$1800.00	1/1/1910	
100-10019	John Doe	Jane Smith	\$1900.00	1/1/1910	
100-10020	John Doe	Jane Smith	\$2000.00	1/1/1910	
100-10021	John Doe	Jane Smith	\$2100.00	1/1/1910	
100-10022	John Doe	Jane Smith	\$2200.00	1/1/1910	
100-10023	John Doe	Jane Smith	\$2300.00	1/1/1910	
100-10024	John Doe	Jane Smith	\$2400.00	1/1/1910	
100-10025	John Doe	Jane Smith	\$2500.00	1/1/1910	
100-10026	John Doe	Jane Smith	\$2600.00	1/1/1910	
100-10027	John Doe	Jane Smith	\$2700.00	1/1/1910	
100-10028	John Doe	Jane Smith	\$2800.00	1/1/1910	
100-10029	John Doe	Jane Smith	\$2900.00	1/1/1910	
100-10030	John Doe	Jane Smith	\$3000.00	1/1/1910	
100-10031	John Doe	Jane Smith	\$3100.00	1/1/1910	
100-10032	John Doe	Jane Smith	\$3200.00	1/1/1910	
100-10033	John Doe	Jane Smith	\$3300.00	1/1/1910	
100-10034	John Doe	Jane Smith	\$3400.00	1/1/1910	
100-10035	John Doe	Jane Smith	\$3500.00	1/1/1910	
100-10036	John Doe	Jane Smith	\$3600.00	1/1/1910	
100-10037	John Doe	Jane Smith	\$3700.00	1/1/1910	
100-10038	John Doe	Jane Smith	\$3800.00	1/1/1910	
100-10039	John Doe	Jane Smith	\$3900.00	1/1/1910	
100-10040	John Doe	Jane Smith	\$4000.00	1/1/1910	
100-10041	John Doe	Jane Smith	\$4100.00	1/1/1910	
100-10042	John Doe	Jane Smith	\$4200.00	1/1/1910	
100-10043	John Doe	Jane Smith	\$4300.00	1/1/1910	
100-10044	John Doe	Jane Smith	\$4400.00	1/1/1910	
100-10045	John Doe	Jane Smith	\$4500.00	1/1/1910	
100-10046	John Doe	Jane Smith	\$4600.00	1/1/1910	
100-10047	John Doe	Jane Smith	\$4700.00	1/1/1910	
100-10048	John Doe	Jane Smith	\$4800.00	1/1/1910	
100-10049	John Doe	Jane Smith	\$4900.00	1/1/1910	
100-10050	John Doe	Jane Smith	\$5000.00	1/1/1910	



## R (K) PROVISIONAL RULES FOR PERIODICAL IN-WATER SURVEY OF LARGE SHIPS

Section 1**GENERAL****Application**

101 These Provisional Rules are intended to apply to the in-water survey of ships, other than passenger ships, less than 10 years old, having a beam greater than 38 m, and to periodical surveys but not to Special Surveys. The ship is to have a suitable high resistance paint applied to the underwater portion of the hull and an approved automatic system of impressed current external cathodic protection.

102 The purpose and extent of the in-water survey is to provide, so far as practicable, information on the condition of the ship and the machinery which is normally obtained from the drydocking survey requirements of C 1. For complete survey of screwshafts, the requirements of C 12 are to be carried out.

103 On application from an Owner, proposals for an in-water periodical survey could be considered for suitably designed ships. On satisfactory completion of an in-water survey, the survey record "IWS" (with date) will be assigned and entered in the *Supplement to the Register Book*.

**Plans**

104 To facilitate in-water surveys, plans showing external details of the hull below the sheerstrake, including the following items, are to be submitted for consideration, together with a key plan indicating their location:—

All shell openings.

Docking plugs.

Bilge keels.

Welded seams and butts.

Appendages.

Anodes, including method of attachment.

Rudder.

Propeller.

Sterngear.

Reference points.

Watertight and oiltight bulkheads are to be indicated, and details of the proposed methods of marking and identification of plates are to be submitted.

105 Photographs of the following items, preferably in colour, are to be supplied either before the ship is launched or at a drydocking:—

In-water shell openings including those for main inlets, discharges and athwartship thrust units.

Rudder closing plates in way of wear down gauge plugs.

Additional items as may be considered necessary.

The photographs are primarily intended for the purpose of identification of the items by the diver at the time of survey.

Principal dimensions and location, together with a suitable scale, are to be indicated on the photographs. Copies of the photographs are to be available on board ship and are also to be provided for the Society's Head Office records.

Section 2**DESIGN**

201 Hull attachments, rudder and sterngear design are to facilitate in-water survey, and any special features in this connection are to be indicated on the plans required by R(K) 104.

202 Means are to be provided for ascertaining the clearance in the sternbush and sufficient access is to be arranged to verify, from external examination, that the oil gland is in order.

203 Means are to be provided for ascertaining the position and identity of each propeller blade from inboard.

204 Rudders are to be designed to facilitate measurement of pintle and bush clearances, and for verifying security of the pintles in their sockets.

205 Means are to be provided for readily changing impressed current anodes and, where necessary, sacrificial anodes. Anodes should normally be bolted to the structure but equivalent means of attachment will be considered.

206 Sea connections, including water boxes, are to be provided with suitable means of blanking to enable shipside valves and fittings to be opened up for examination and repair as required. It is recommended that the external blanking components be carried on board.

Where considered necessary, combined pressure release and drain valves or cocks, with permanently attached



blanking arrangements, are to be fitted on the sea connections in accessible and visible positions.

Shipside gratings are to be hinged where practicable.

**207** Provision is to be made for ready identification of bulkheads and frames above the waterline. For this purpose, it is recommended that transverse primary members and bulkhead numbers be marked at the weather deck edges and that the position of watertight and oiltight bulkheads be indicated near the load waterline.

Welded beads for identification marking are not to be used on the hull. However, welded beads or cutting would be permitted on the gutterway bar, if fitted.

**208** Means of identification on the flat of bottom are to be provided, for example, by longitudinal and transverse lines painted on the plates. Details of the proposed system of marking are to be submitted for consideration.

**209** Details of the above items are to be submitted to the Society for approval before a ship is accepted for in-water survey.

**210** Proposals to carry out an in-water survey on ships not fully complying with these Provisional Rules will be specially considered.

### Section 3

#### **APPROVAL OF FIRMS FOR IN-WATER SURVEYS**

**301** Diving and in-water survey operations are to be carried out by firms recognized by the Committee.

For the purpose of recognition, the firm will be required to demonstrate to the satisfaction of the Surveyor that it has:—

- (a) A clearly defined management structure with responsibility for each activity indicated.
- (b) Sufficient staff suitably qualified and experienced for the work undertaken, including divers with adequate knowledge of ship construction, hull survey and repair work.
- (c) Sufficient equipment which has been proved by actual or simulated tests to be suitable for the work undertaken.
- (d) All equipment maintained in good condition, recording equipment regularly calibrated in accordance with recognized standards, and a record of each important item.

**302** The firm is to maintain records of divers employed for:—

In-water survey work.

Camera work.

Non-destructive testing.

**303** On completion of inspection and assessment of the firm's equipment and experience, the Surveyor's report is to be submitted for the consideration of the Committee.

**304** Continued recognition by the Committee will be dependent on the standards of the firm being maintained, and the Society's Surveyors may occasionally require the firm to demonstrate that this is being done.

### Section 4

#### **SURVEY REQUIREMENTS**

**401** The in-water survey is to be carried out under the supervision of a Surveyor to the Society, with the ship at a suitable draught (mean draught generally not exceeding 6 m) in sheltered waters; the in-water visibility is to be good and the hull below the waterline is to be clean. The Surveyor is to be satisfied that the method of pictorial presentation is satisfactory and that the information obtained enables a reliable assessment to be made of the condition of the hull. The services of a diver are also to be available for this purpose, and there is to be good two-way communication between the Surveyor and the diver.

**402** Spare parts should be carried on board for all items that a diver is likely to remove for underwater inspection.

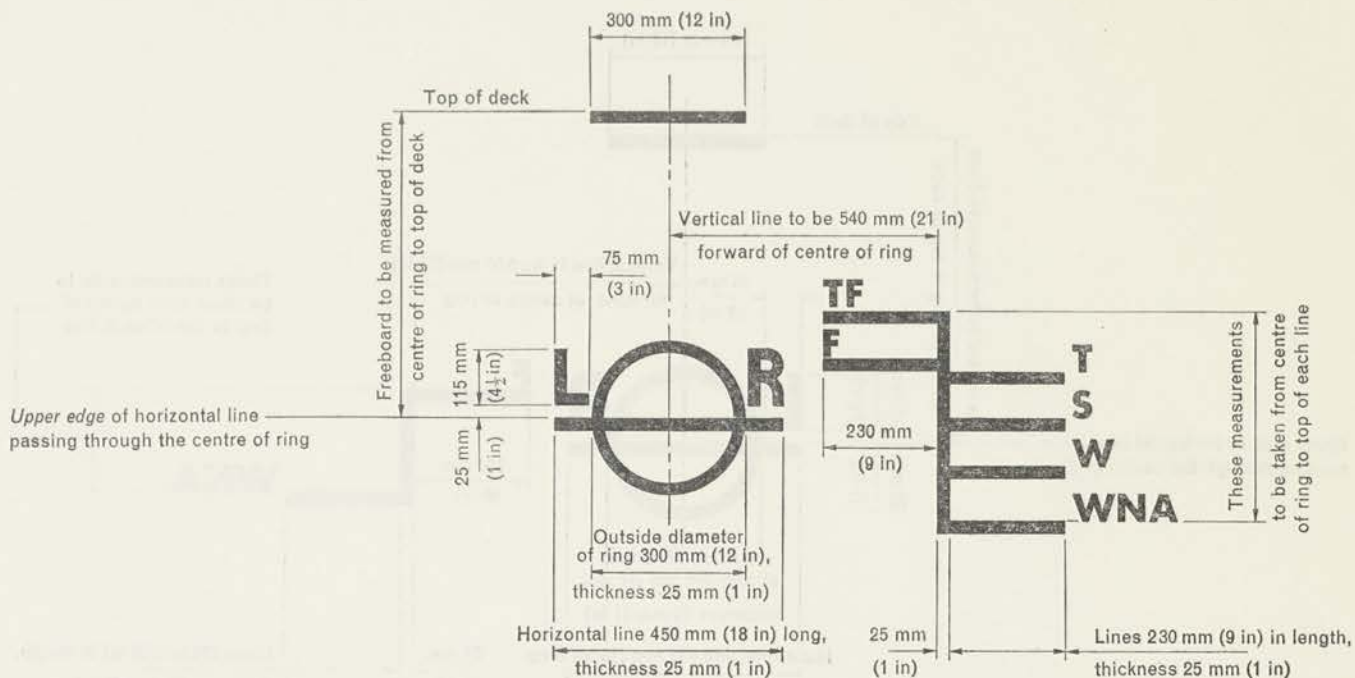
**403** Where closed-circuit television with cameras mounted on a submersible vehicle is used by an approved firm to conduct an in-water survey, arrangements are to be such that the vehicle can be remotely controlled. The vehicle is to be fitted with at least two television cameras, one for viewing ahead to obtain an assessment of the general condition of the hull and a second camera mounted perpendicular to the hull to give a detailed view of any particular area of the hull below the waterline.

Provision is also to be made to take still colour photographs of any areas called for by the Surveyor.

**404** Means other than closed-circuit television may be used for obtaining detailed information of the condition of the hull, but particulars of the method are to be submitted for consideration before the in-water survey is commenced.

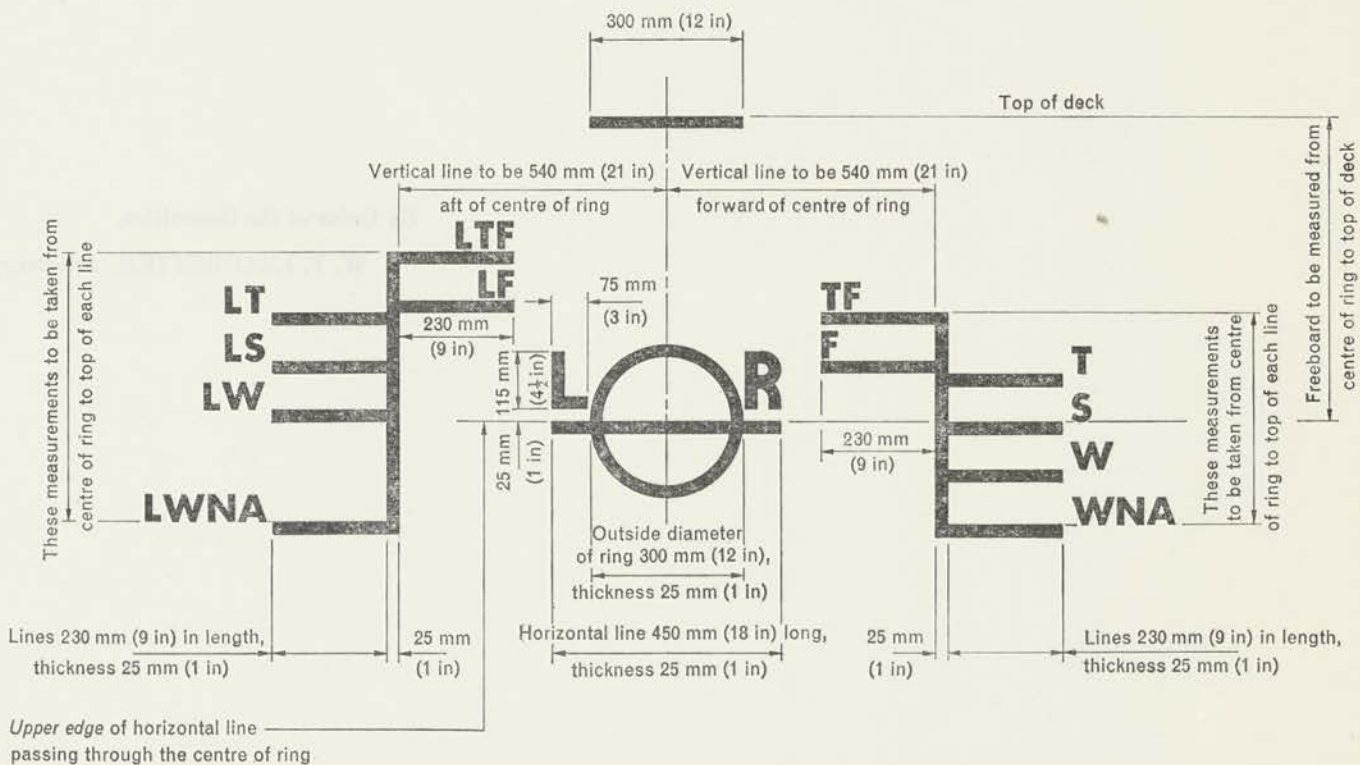


### TYPICAL FREEBOARD MARKING FOR SHIPS



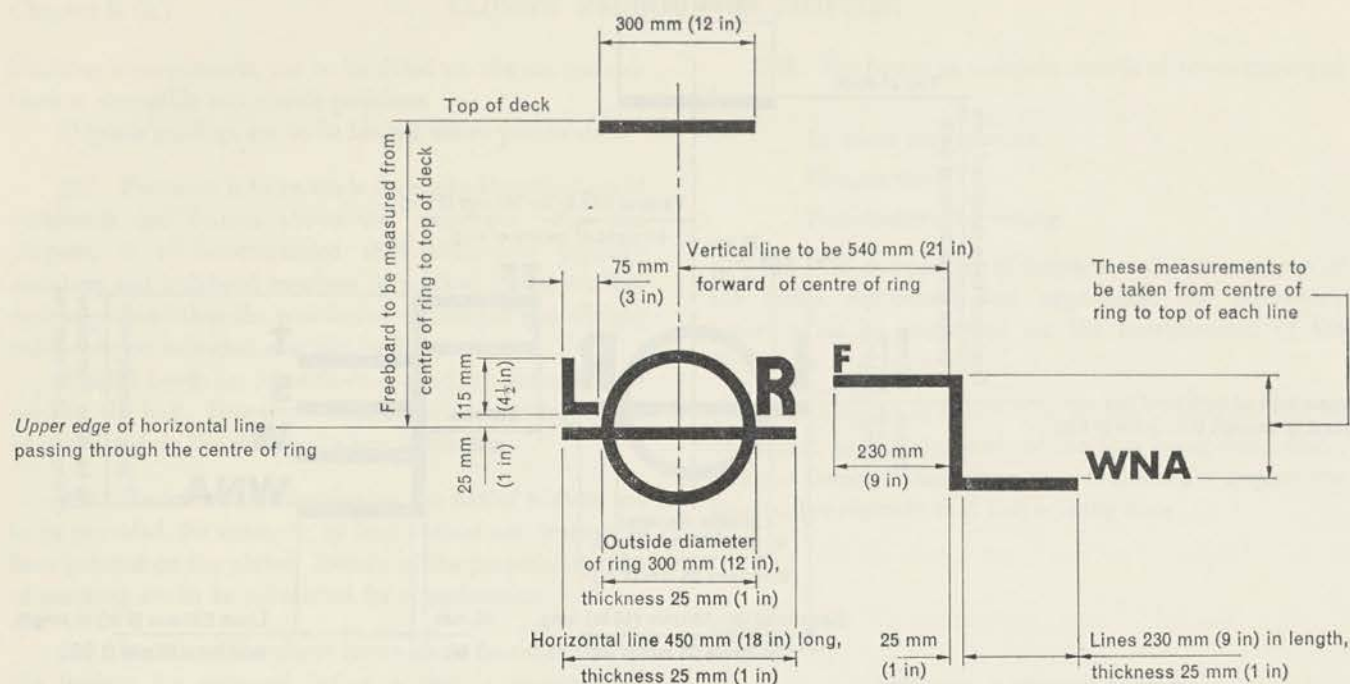
The centre of the ring is to be placed on both sides of the ship amidships, i.e. at the middle of the length as defined in the International Load Line Convention 1966. The ring, with applicable lines and letters, are to be painted in white or yellow on a dark ground or in black on a light ground. They are also to be permanently marked on the sides of the ship to the satisfaction of the Administration. The marks are to be plainly visible and, if necessary, special arrangements are to be made for this purpose. Ships over 100 m (328 ft) in length are not required to be marked with the WNA line.

### TYPICAL FREEBOARD MARKING FOR SHIPS CARRYING TIMBER DECK CARGOES



The centre of the ring is to be placed on both sides of the ship amidships, i.e. at the middle of the length as defined in the International Load Line Convention 1966. The ring, with applicable lines and letters, are to be painted in white or yellow on a dark ground or in black on a light ground. They are also to be permanently marked on the sides of the ship to the satisfaction of the Administration. The marks are to be plainly visible and, if necessary, special arrangements are to be made for this purpose. Ships over 100 m (328 ft) in length are not required to be marked with the WNA line. For such ships the LWNA line is to be level with the W line.

# TYPICAL FREEBOARD MARKING FOR SAILING SHIPS



The centre of the ring is to be placed on both sides of the ship amidships, i.e. at the middle of the length as defined in the International Load Line Convention 1966. The ring, lines, and applicable letters are to be painted in white or yellow on a dark ground or in black on a light ground. They are also to be permanently marked on the sides of the ship to the satisfaction of the Administration. The marks are to be plainly visible and, if necessary, special arrangements are to be made for this purpose.

By Order of the Committee,

W. T. LEADBETTER, *Secretary*





# THEORY OF THE ELECTRIC CIRCUIT



The diagram illustrates the relationship between the various quantities in an electric circuit. The central component represents the source of electromotive force, which drives the current through the circuit. The resistor represents the opposition to the flow of current, and the potential difference is the work done per unit charge in moving the charge through the circuit. The electric charge is the quantity of electricity that flows through the circuit.

THEORY OF THE ELECTRIC CIRCUIT









